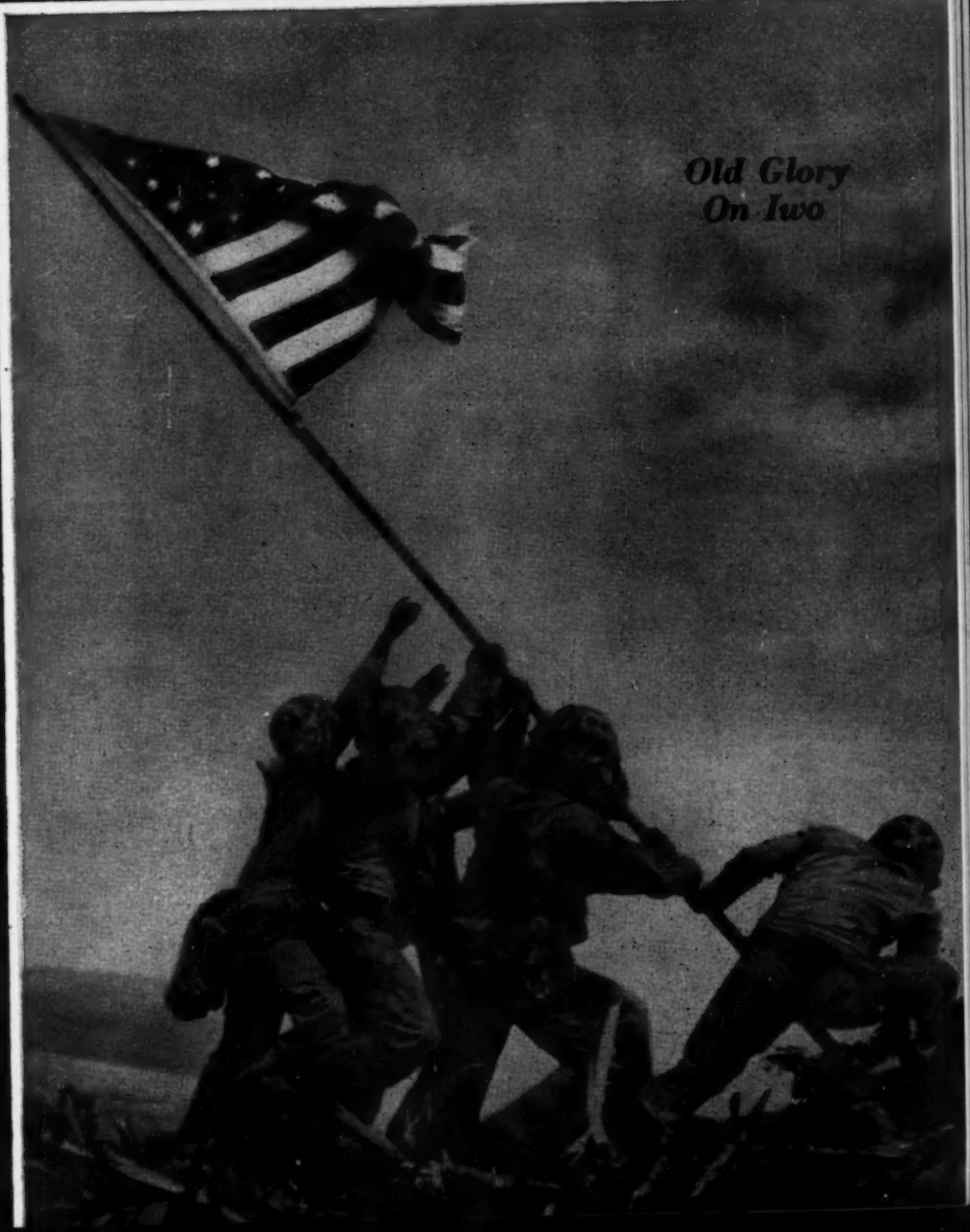
WATER WORKS & SEWERAGE

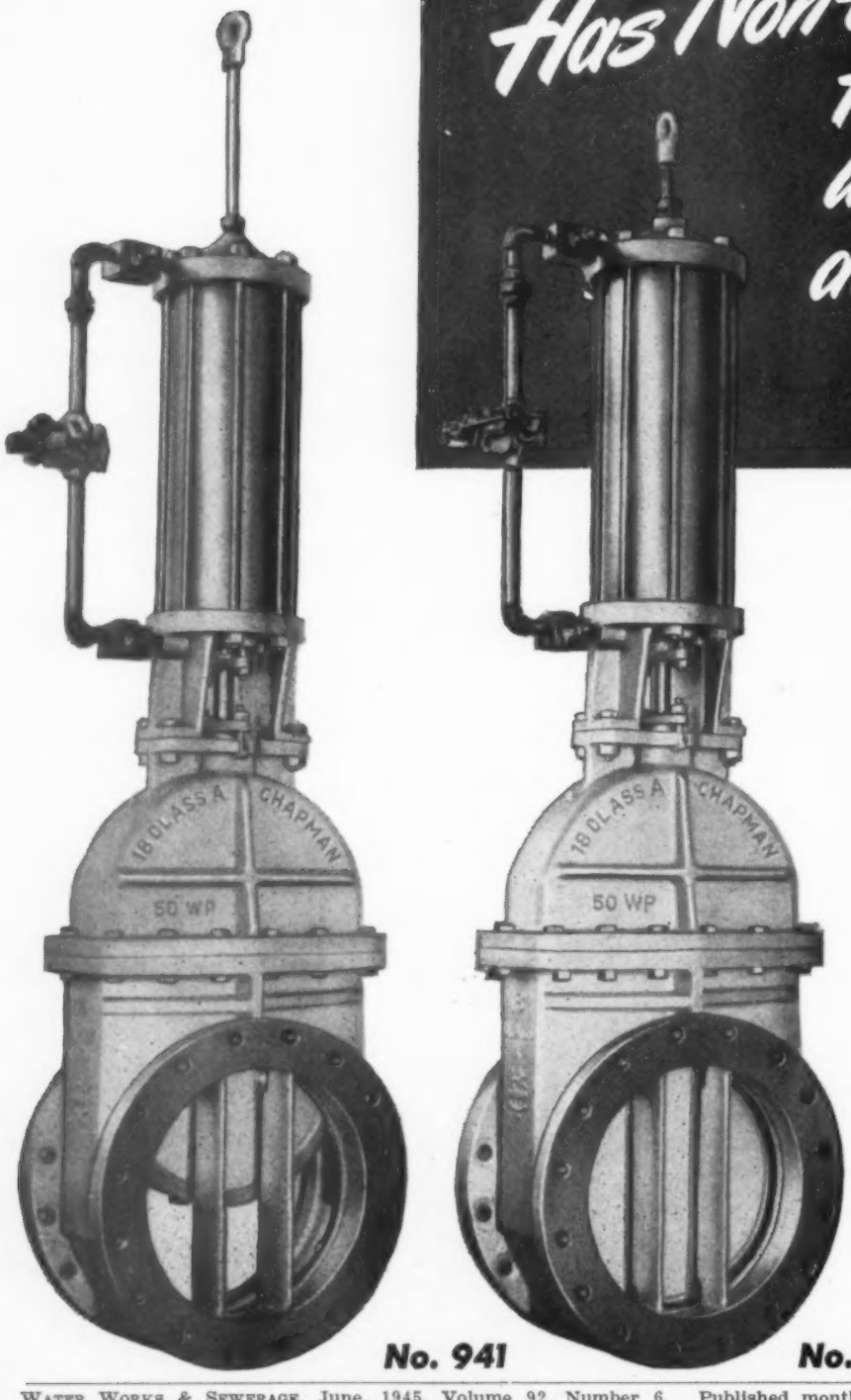


Old Glory On Iwo

CHAPMAN

BEAMED WATERWAY GATE VALVE

Has "Non-Tipping" Disc to eliminate uneven wear and minimize leakage



No. 941 **No. 940**

Recognizing the need for a more efficient valve than the double disc, parallel seated gate valve used under throttling conditions, Chapman engineers developed the Beamed Waterway Gate Valve.

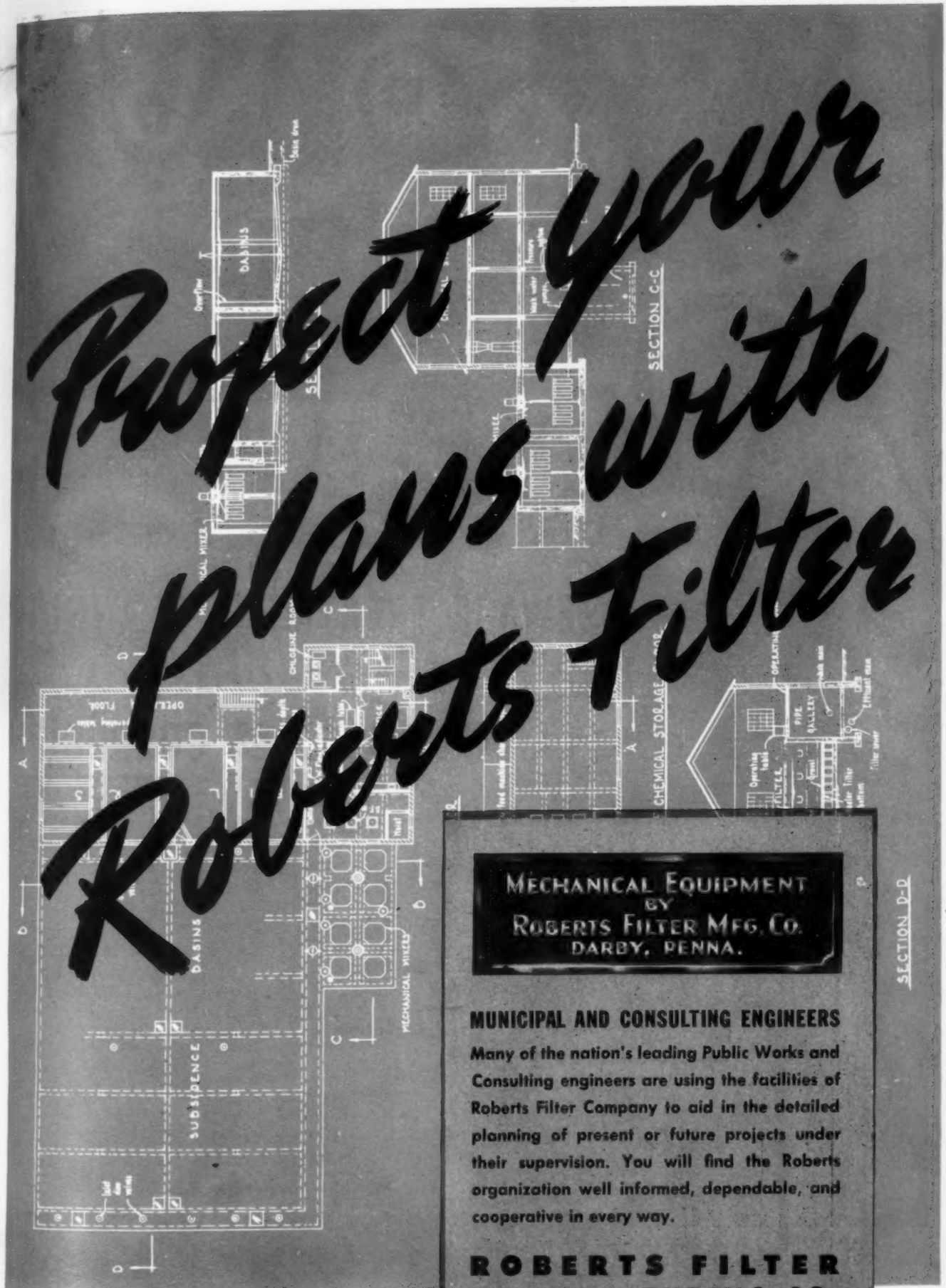
This valve is designed to provide sufficient bearing contact for the downstream disc to prevent its tipping into the waterway. This is effected by means of bronze-faced vertical beams in the downstream port, which contact bronze strips in the adjacent disc. The bronze facings are in the same plane with the seat and disc ring faces, thus increasing the bearing contact between disc and body seat facings from six to ten times when the valve is in the one-quarter or one-half open positions. There is no uneven wear on the seat rings to cause the valve to leak.

Beamed Waterway Gate Valves have been tested in actual operation for more than ten years, and conclusive reports from Water Filtration Plants are now available to engineers. Write to:

The Chapman Valve Manufacturing Co.

INDIAN ORCHARD, MASS.

WATER WORKS & SEWERAGE, June, 1945, Volume 92, Number 6. Published monthly by Gillette Publishing Co., 330 South Wells Street, Chicago, Ill. Per copy, 25c, except *this issue 75 cents*. Subscr iption rate, United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under act of March 3, 1879.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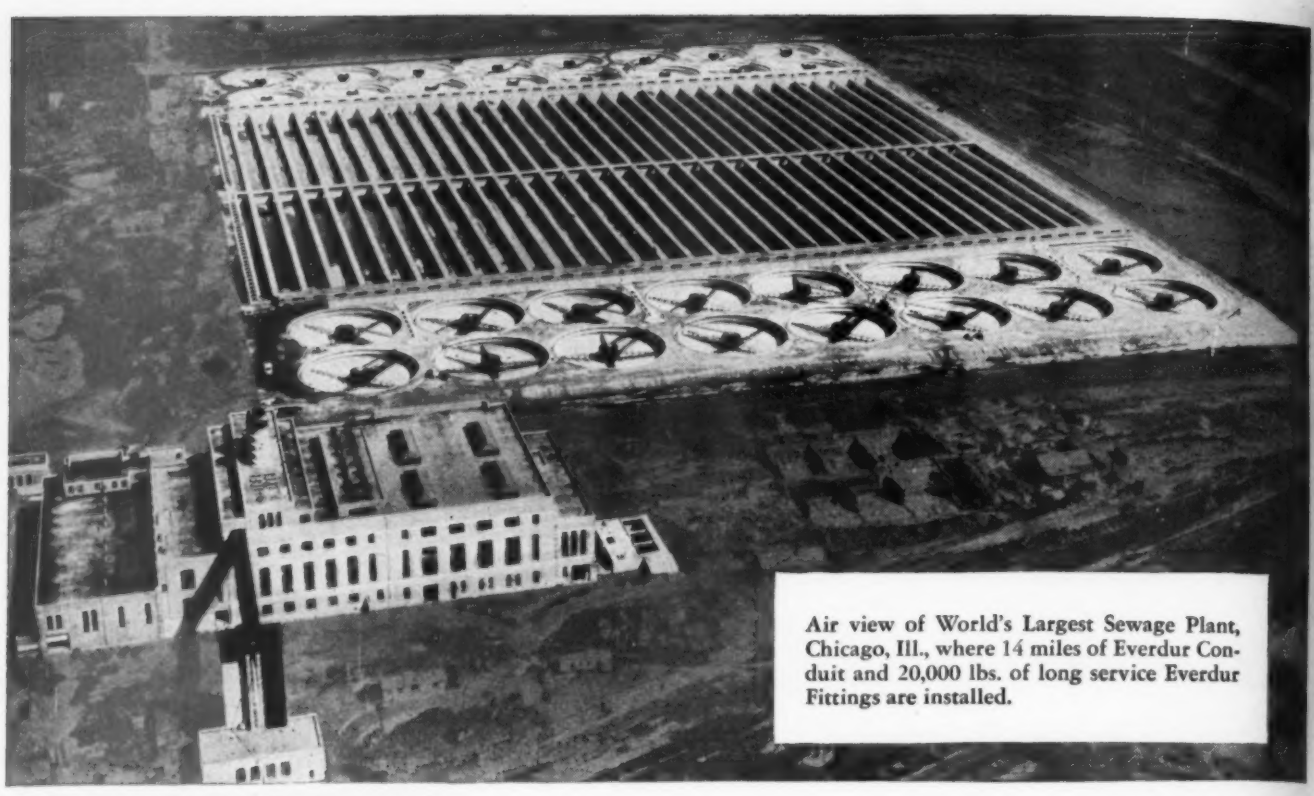

Air view of World's Largest Sewage Plant, Chicago, Ill., where 14 miles of Everdur Conduit and 20,000 lbs. of long service Everdur Fittings are installed.

Laughlin Automatic Traveling-Type Screen installed in the Dearborn, Michigan Sewage Treatment Plant. The Everdur blades have taken twelve years of punishing service, yet are still sound.

Float Tubes, 12 inches diameter, 45 feet long, fabricated of Everdur Sheet, welded. Designed by Krajewski-Pesant Mfg. Corp. for use in Wards Island Sewage Disposal Plant, New York. After seven years of service the float tubes are in excellent condition.

SEWAGE TREATMENT PLANNING

also involves

PLANNING AGAINST CORROSION

FROM THE INITIAL SCREENING of raw sewage to the removal of dried sludge, the operation of the modern sewage treatment plant is a battle against corrosion—against the deteriorating effects of gases, moisture, moisture-saturated air and the corrosive action of sludge. Many metals, which under normal conditions of use would give years of trouble-free service, break down under the corrosive influences attending the processing of sewage.

That is why *Everdur** (copper-silicon alloy) is specified for so many heavy-duty service jobs in sewage plants. Everdur combines the corrosion resistance of pure copper with the tensile strength of mild steel. It is readily welded, and has high resistance to fatigue. For detailed information on *Everdur Metal* write for Publication E-11.

*Reg. U. S. Pat. Off.

EVERDUR METAL

is used in sewage works for Coarse and Fine Screens, Swing Gates, Built-up Sluice Gates, Coarse Bar Rack Aprons, Effluent Weirs and Scum Weirs, Structural Scum Baffle Brackets, Troughs, Screen Hoppers, Orifices, Baskets, Anchors, Ladders, Float Gage Chains, Valve Springs, Manhole Steps, Guides, Walkways, Bars and Plates, Bolts and Nuts.

44138

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THE AMERICAN BRASS COMPANY—General Offices: Waterbury 88, Conn.

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Objective: SANITATION
Obstacle: CONTAMINATION
Weapon: Perchloron
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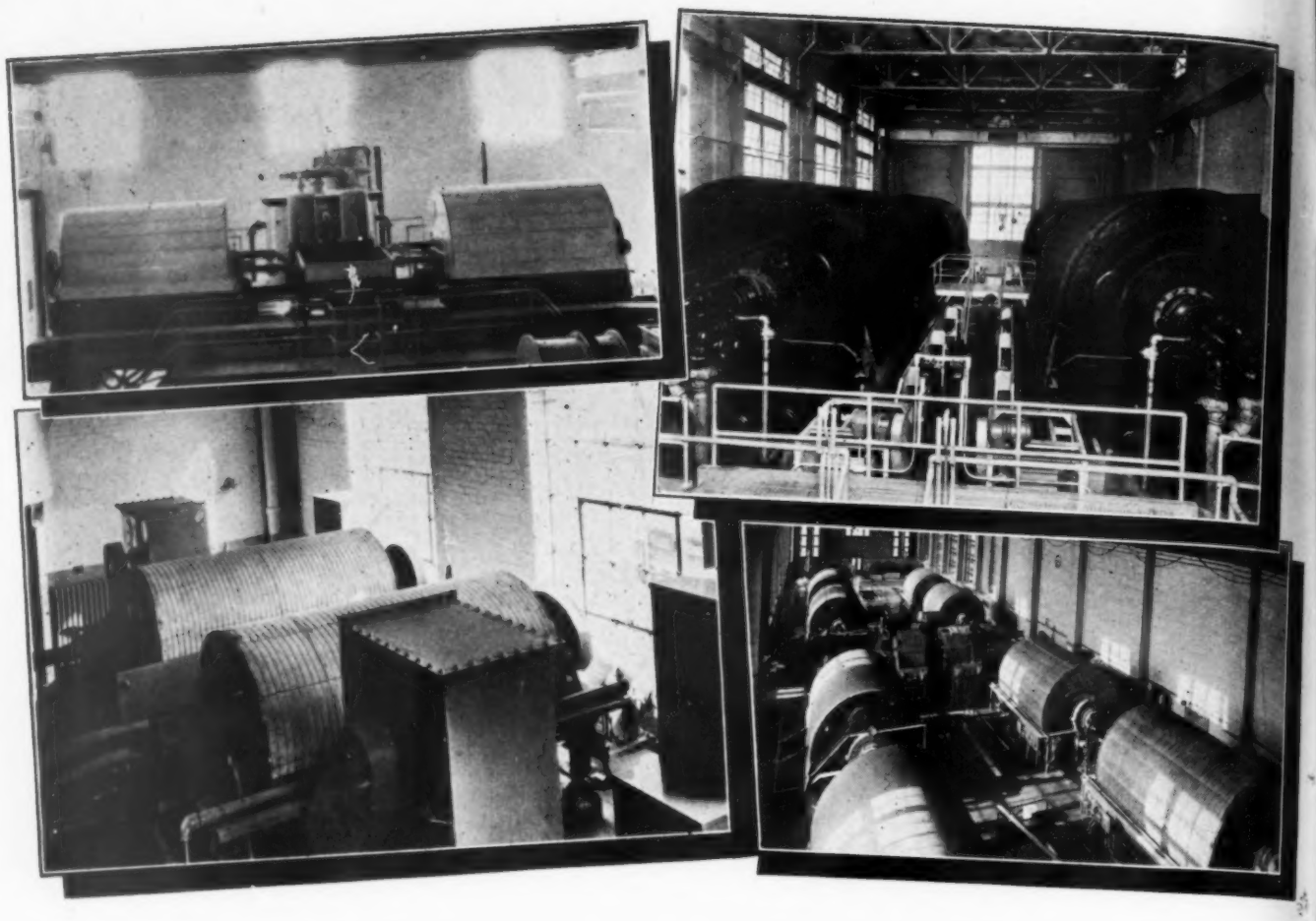

CONSTRUCTIVE PLANNING NOW WILL AID CIVIC GROWTH

Conkey Sludge Filters have for years efficiently dewatered various types of sludges and wastes in large and small communities.

Adequate plans for dewatering domestic or partially industrial sewage sludges made *now* will mean healthy, happy communities and will provide, when needed, useful public works of a permanent nature.

Municipal and consulting engineers appreciate the advantage of working with an organization whose equipment is backed by undivided responsibility for design, engineering, fabrication and initial operation.

Conkey Sludge Filters are designed by engineers who understand feed consistency, conditioning chemicals, conditioning time, application and mixing, and built by workmen who know how to construct sludge filters.

Over a thousand tons of dry solids are dewatered daily in American communities — large and small — on Conkey Sludge Filters. Thirty years' experience in dewatering sludges is available to you by calling in a General American engineer to assist in your planning.

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AQUA NUCHAR *Hits the Beach!*

. . . the pummelling of enemy shores by our aircraft and naval bombardment . . . the herding together of destroyers, landing craft and other great and small navy ships . . . then the troops . . . hitting the beach, wave after wave after wave!

The beachhead is established . . . out of the blood and sweat of American soldiers, sailors and marines. After the first tenuous strip of beach is won and held, supplies roll and float ashore. Among these necessities is Aqua Nuchar Activated Carbon, packed in special, watertight drums for overseas consumption. Yes, Aqua Nuchar follows the fighting men because it is necessary to insure crystal-clear water for our forces. Aqua Nuchar is the activated carbon with millions of tiny particles that ADsorb algae odors and other foreign elements that cause bad taste and odor in water. It also removes impurities which might be placed in the water by the enemy.

Aqua Nuchar is extensively used at home, too . . . and has been employed for many years in over 1,200 communities by outstanding waterworks superintendents.

To assure clear, palatable water for your community, use Aqua Nuchar Activated Carbon. Put ADsorption to work for you!

BLUEPRINT NOW

But above all, remember there is a war yet to be won. Maintain equipment to assure operation at 100% efficiency.

NUCHAR — INSURES PALATABLE DRINKING WATER

INDUSTRIAL CHEMICAL SALES

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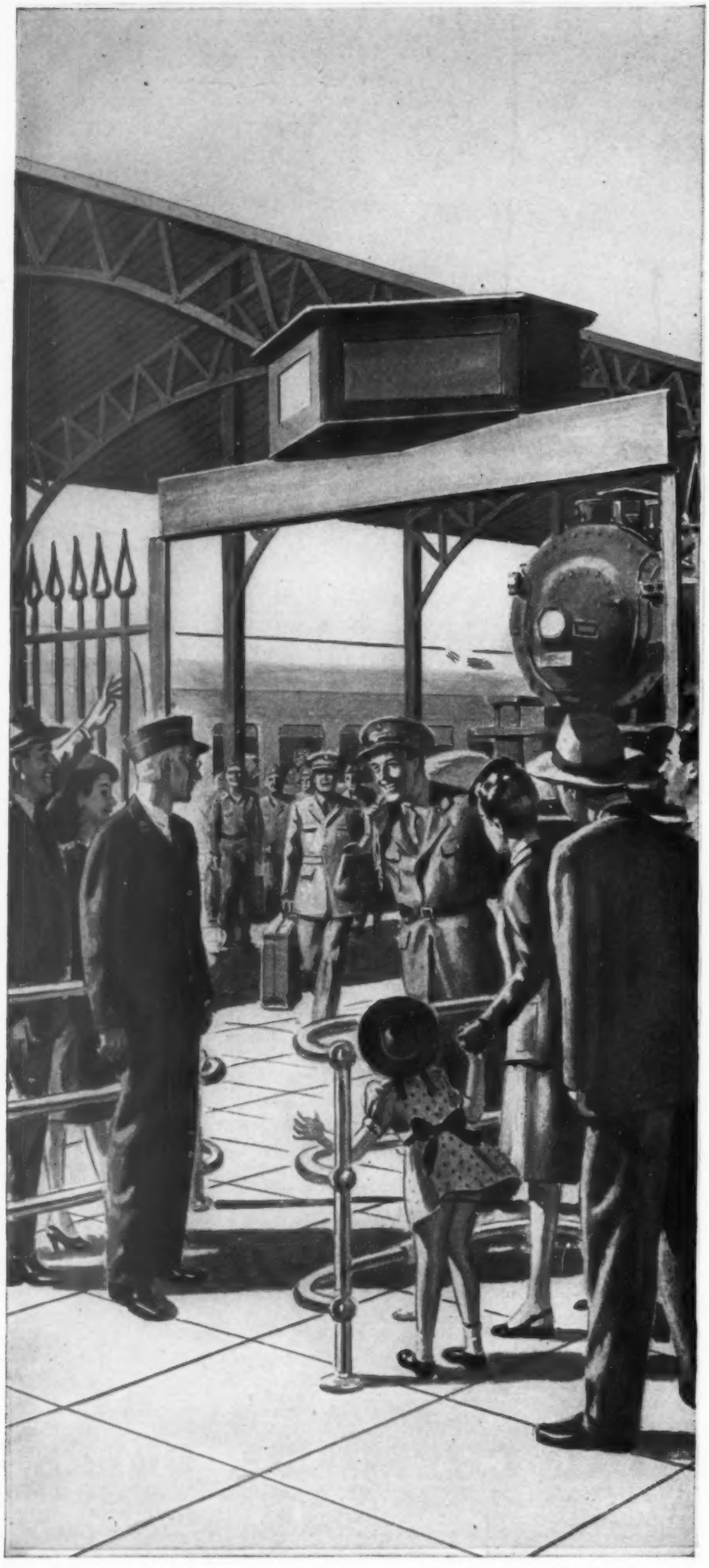


Is this

Peace may still be far away.

Or it may be closer than you think...

But near or far, final victory will bring two certainties to affect your job.

First, there will be changes in American living—for revolutionary peacetime progress has followed close on the heels of *every* modern war. And *you* will have a great part to play in the coming postwar America!

Among other things, we believe the postwar period will see an important revolution in municipal life: *the merging of food wastes and human wastes in a* SINGLE *system of collection and disposal, by water-carriage methods.*

This idea is already more than a decade old and was well on the way to general acceptance when the war began.

We believe that the garbage can, as a part of the American home—and the separate collection of garbage, as a part of municipal activity—will ultimately become as extinct as the outhouse.

The G-E DISPOSALL—a mechanism for converting food waste into sewage by shredding, and then flushing it down the drain—makes this revolution possible.

It involves no new problems for municipal sewage disposal systems—for food wastes and human wastes are basically identical.

You, in your vital job of assisting human progress, after the war, will want to be familiar with the Disposall.

YOUR QUESTIONS AND OUR ANSWERS about the G-E Disposall

1. Is the Disposall a tested product—or just an "idea"?

Answer: The first Disposall was marketed in 1935. It has spent its first decade proving the soundness of its principles.

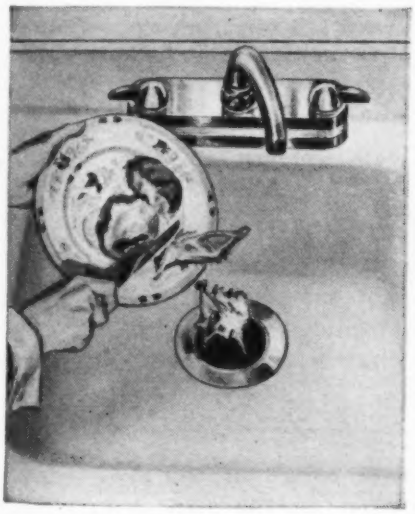
a part of your postwar job . . . . ?

It is ready to become a new way of life, in the postwar period, only because more than ten years of preparation lie behind it.

2. Won't the Disposall create new problems in sewerage systems?

Answer: No. Ten years of tests have amply substantiated the fact that solids already in your sewer lines and treatment plants are not in any significant way different from the shredded food wastes flushed into your system by the Disposall.

Quantitatively, widespread use of the Disposall will call for greater *capacity* in your plants some day—but never for any change in your *methods* of treatment.



3. What is there to gain by this dual disposal?

Answer: Garbage—which is to say, food wastes which have putrefied—is too dangerous to store in the home, or near it. It would be difficult to overestimate the diseases caused by the flies it breeds, the rodents it attracts.

Even *polio* is now on the list of more than a score of disease indictments against the common housefly!

In addition, garbage is odorous and unpleasant. With the Disposall, food wastes are shredded and water-flushed out of the house *before* they putrefy into garbage!

4. If this change is so logical, why hasn't it come sooner?

Answer: "Precedent"—or the absence of precedent—is the only answer we can think of.

Originally, sewers were regarded as drains for storm water only—the idea of putting *any* solids into them was unheard of!

Later, the idea of removing human wastes by water-carriage methods developed. The idea of human-waste removal is about fifty years old; the idea of food-waste removal by the same means is about ten years old.

5. Why "grind" the food waste so small?

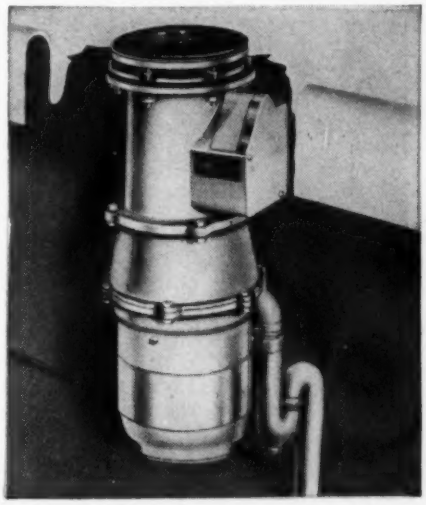
Answer: Since *size* alone has hitherto prevented dual disposal of food wastes and human wastes by water, it is obvious that some grinding is necessary.

The very fine particles turned out by the Disposall represent the carefully tested, safe dimensions at which particles *will not shoal* at any sewer velocity in common use but will be amenable to clarification, digestion, and stabilization at treatment plants.

6. If we have no sewage treatment plant, what then?

Answer: With widespread use of the Disposall—with *any* use of the Disposall—or with *no* Disposalls at all, we believe a sewage treatment plant is an absolute "must" in any American city.

We hope that the Disposall—by providing still *another* reason for such a plant—will help those public-spirited men who have long been fighting for such facilities!



7. Where can I get more information?

Answer: Comprehensive tests of the Disposall, in actual use, over a period of more than ten years, have given us reliable data on its use.

The net result of this material shows that no new problems of any nature will be created by the Disposall.

For complete data, or any special information, please write to: GENERAL ELECTRIC COMPANY, Dept. WWS 65, Schenectady, New York.

GE Disposall

CONVERTS FOOD WASTE TO SEWAGE—ELIMINATES "GARBAGE"

GENERAL ELECTRIC

PURE WATER— The Easy HOODCHLOR Way Overseas and at Home

BEACHHEAD AT LEYTE
Official U. S. Navy Photo

WATER POINT SET UP AT LINGAYEN, LUZON
U. S. A. Signal Corps Photo

As essential as machine guns at the fighting front pure drinking water is easy to obtain even in the most remote jungles by means of HOODCHLOR. Now used on most fighting fronts as well as by many municipal and private water works throughout the United States.

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HIGH TEST HYPOCHLORITE

When HOODCHLOR is fed into the drinking water supply it quickly destroys and prevents growth of dangerous bacteria. This high test calcium hypochlorite in free-flowing granular form retains its strength for a year or more. Rapid rate of solubility enhances its convenience.

HOODCHLOR is widely used in this country by municipal and private water systems of not over 500,000 gallons daily capacity and by larger works for emergency use. It destroys slime and algae in reservoirs, tanks and mains.

HOODCHLOR is also extensively used in sewage treatment, and for sterilizing swimming pools. Many municipalities keep a supply on hand for emergency use when fires, explosions, floods, or other disasters disrupt the regular supply.

HOODCHLOR is now shipped in convenient resealable steel pails, lined with chlorine resistant lacquer. Net weight 25 pounds. Also packed in 3¾ lb. cans, 12 to the case; and 5 lb. cans, 9 to the case.

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CAUSTIC SODA · BICARBONATE OF SODA · SODA ASH · CHLORIDE OF LIME

Horton Elevated Storage

means Reduced Power Costs • Minimized Pressure Fluctuations

A 60,000 gal. Horton elevated storage tank at Newton, Ga. Note how this streamlined ellipsoidal tank blends with the surroundings.

Many engineers have found the solution to the problem of smoothing out water pressure variations through the installation of Horton elevated storage. They have also found that Horton elevated storage . . . in addition to providing a reserve of water that keeps pressure uniform . . . enables a municipality to meet severe hourly peak demands.

The Horton elevated storage tank shown above . . . which has a capacity of 60,000 gal. . . . installed at Newton, Ga. . . . is an important part of that municipality's water works distribution system. The height of this structure is 75 ft. to bottom.

While most engineers are well acquainted with the advantages such as: lower pumping costs, added reserve for fire protection, and a provision for pumping during off-peak periods, not all have full particulars about Horton elevated storage.

If you are concerned with the planning or revision of water distribution systems, it will be worth your while to investigate Horton elevated storage facilities. Write to any of the offices shown below. We'll send you estimating costs of fabrication and erection of Horton elevated storage.

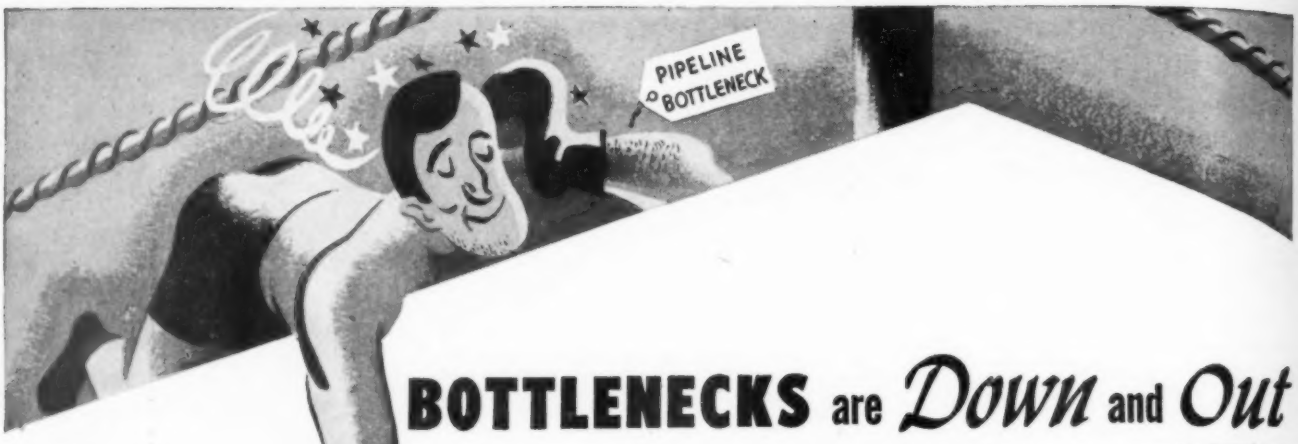
CHICAGO BRIDGE & IRON COMPANY

Chicago 4.....2198 McCormick Bldg.
New York 6.....3390-165 Broadway Bldg.
Cleveland 15.....2262 Guildhall Bldg.
Los Angeles 14.....1455 Wm. Fox Bldg.
Birmingham 1.....1586 North 50th Street

Plants in Birmingham, Chicago and Greenville, Pa.

Tulsa 3.....1646 Hunt Bldg.
Houston 1.....5615 Clinton Drive
Philadelphia 3.....1644-1700 Walnut Street Bldg.
Washington 4.....703 Atlantic Bldg.
San Francisco 11.....1283-22 Battery St. Bldg.

In Canada: Horton Steel Works, Limited, Fort Erie, Ont.



BOTTLENECKS are *Down* and *Out*

WHEN YOU SPECIFY

a.c.f. LUBRICATED PLUG VALVES with

STRAIGHT THROUGH FULL PIPE AREA PORT OPENING

The cylindrical plug of the a.c.f. Lubricated Plug Valve provides a round-cornered, full pipe-area port opening which assures (1) *unrestricted* flow and full pressure of fluids throughout your pipe lines (2) longer valve life — since flow velocities are not increased and abrasion is reduced. The over-all result is maximum efficiency at minimum cost in time, labor and power.

a.c.f. Lubricated Plug Valves have straight through ports. There is no change in direction of the flow. Seating surfaces are sealed away from the flow stream when in the open position — exactly the *opposite* of the exposed seating elements of valves which deteriorate from the cutting and abrasive action of ladings. Tight seating is achieved because seating surfaces are not damaged by lading flow. a.c.f. Lubricated Plug Valves need no auxiliary packing — they are thoroughly sealed by a resilient, easily renewable lubricant gasket. Representatives in principal cities carry adequate warehouse stock for quick delivery.

"TAILOR-MADE" FOR SEWAGE LINES

Liquids bearing solids in suspension such as sewage sludge and most granulated or similar solids are easily controlled. Send for Catalog No. 3-W.

a.c.f. AMERICAN CAR AND FOUNDRY COMPANY

VALVE DEPARTMENT

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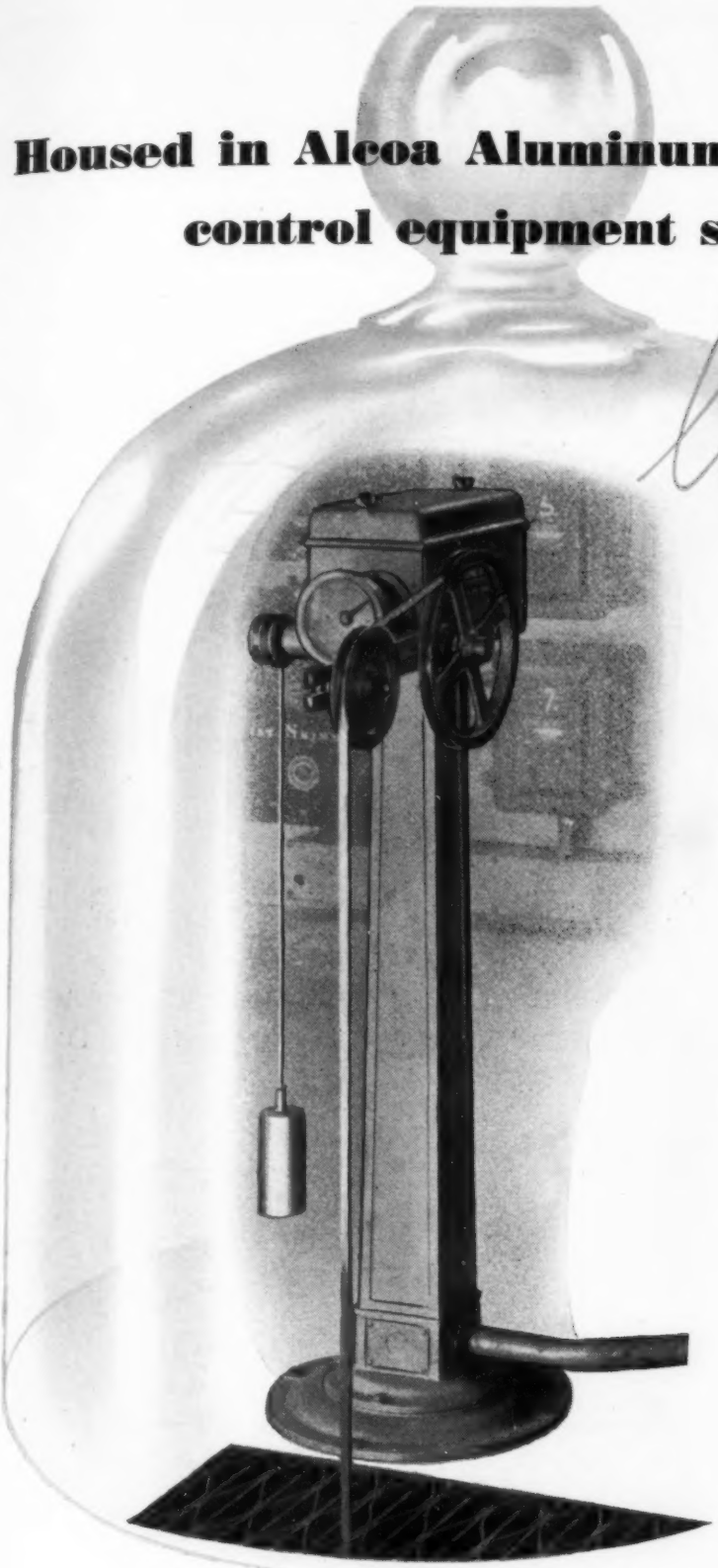
Housed in Alcoa Aluminum, control equipment stays "like new"



Alcoa Aluminum has proved its ability to stand up under many adverse conditions.

"Much of our control equipment employs aluminum enclosures, because of the corrosive conditions under which it must operate. To our knowledge, we have never had to replace an enclosure because of deterioration. And examination of the controls after some years of service shows them still 'good as new'."

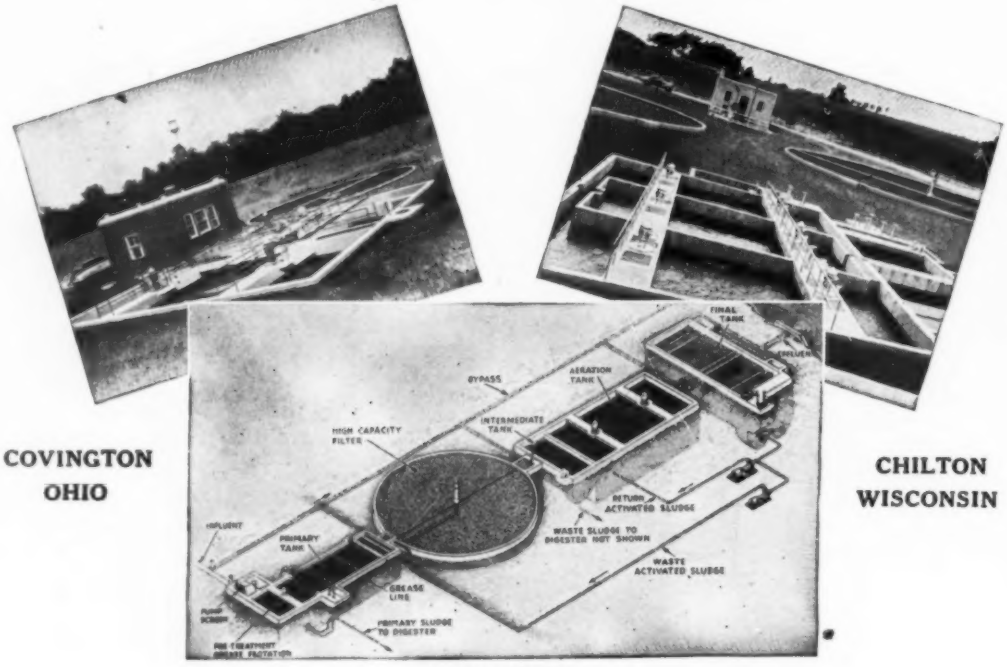
Thus writes Automatic Control Company, manufacturers of liquid level and pressure controls. Again confirming that it pays to use Alcoa Aluminum.

Specify that your equipment is to be housed in aluminum, and save on upkeep. Alcoa Aluminum is available for such purposes, upon WPB approval. ALUMINUM COMPANY OF AMERICA, 1955 Gulf Building, Pittsburgh 19, Penna.

ALCOA FIRST IN ALUMINUM

American Bio-Activation

WASTE TREATMENT



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Bio-Activation combines the best qualities of both the trickling filter and the activated sludge process to produce a completely stable, nitrified effluent, low in B. O. D. and suspended solids.

TYPICAL OPERATING RESULTS

	Domestic, Malt, Brewery and Canning Wastes	
	5 BOD	Suspended Solids
Raw Waste	342	370
Primary Effluent	235*	134
Influent to Filter	510†	.....
Filter Effluent	99	143
Intermediate Effluent	58	65
% Reduction Filter Influent through Intermediate Effluent	89.5	.....
Final Effluent	13	15
% Overall Removal	97.5	96

*High Soluble 5 BOD from malt and brewery.
†Pea waste; 600-1200 ppm. 5 BOD, added in primary effluent.

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Preferred Protection

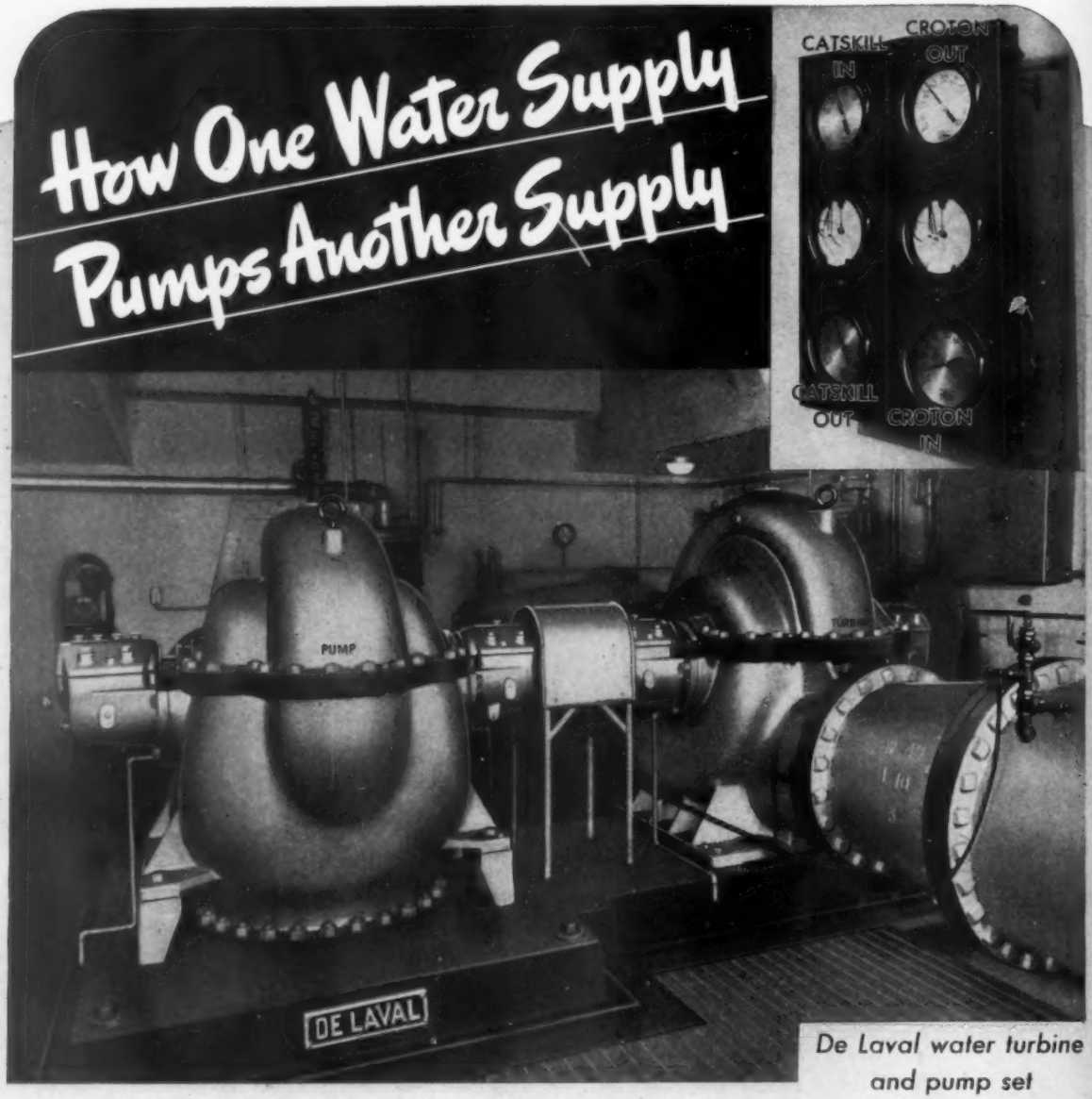
Your guarantee of dependable protection for water supplies is the uniformity, purity and highest quality of Diamond Liquid Chlorine.

DIAMOND ALKALI COMPANY

Pittsburgh 22, Pa., and Everywhere

DIAMOND LIQUID CHLORINE

How One Water Supply Pumps Another Supply



De Laval water turbine and pump set

The De Laval Water Turbine and Centrifugal Pump set here shown is located in a room beneath one corner of the Public Library, 40th St. and Fifth Avenue, New York City. At full capacity the water turbine, receiving 20,800 g. p. m. of Catskill water under 210 ft. head and discharging to its distribution system against 120 ft. head, drives a pump operating at 560 r. p. m., which delivers 21,000 g. p. m. of Croton water to its distribution system against 100 ft. head. The positive head at the suction nozzle is 35 ft. and 392 hp. is delivered by the water turbine.

The speed of the unit is automatically regulated by a hydraulically operated throttle valve in the turbine discharge line, actuated by the pressure therein. No particular attention is necessary other than occasional inspection of the lubricating system.

De Laval engineers will gladly help in solving your pumping problems.

4107

DE LAVAL *Steam Turbine Co.*
TRENTON, N. J.

MANUFACTURERS OF TURBINES . . . STEAM, HYDRAULIC. PUMPS . . . CENTRIFUGAL, CLOGLESS, ROTARY DISPLACEMENT, MOTOR-MOUNTED, MIXED FLOW, PROPELLER. PRIMING SYSTEMS; CENTRIFUGAL BLOWERS and COMPRESSORS. GEARS . . . WORM, HELICAL and FLEXIBLE COUPLINGS

MAINTENANCE TIPS
FOR CORROSIVE SEWAGE SERVICES

If your VENT STACKS are failing too early— and too often—

Vent stacks that carry moist gases from raw or treated sewage are almost sure to be maintenance headaches . . . unless the proper material is used.

Carbon and sulfur compounds in the gas combine with the moisture to form destructive acids that make short work of ordinary vulnerable materials. Modifying the corrosive conditions is difficult, if not impossible. The best and simplest solution is that followed by the eastern plant which erected the 60-foot vent stack illustrated . . . use Byers Wrought Iron.

The durability of wrought iron in this, as in other corrosive sewage plant services, comes from its unique structure. Tiny fibers of glass-like silicate slag—250,000 or more in each square inch of cross-sectional area—are threaded through the main body of high-purity iron. When corrosion encounters these fibers, it is halted and deflected uniformly over the entire surface, instead of tending to localize as it does with ordinary materials. The fibers help to anchor the initial protective scale, which shields the underlying metal. And when galvanizing is used, wrought iron's microscopically rougher surface takes and retains a heavier coat.

How successfully wrought iron combats the aggressive attack of sewage gases is indicated by its widespread utilization. Some of the country's newest, largest disposal plants use it for ducts, for gas collecting hoods and domes, for gas lines, and for waste heat boilers. If you are not now using wrought iron in any of these services, you'll find it profitable to investigate its record.

Our technical bulletin, "Wrought Iron for Sewage Treatment and Disposal Installations," illustrates and describes a number of the wrought iron applications in modern plants. We will be glad to send you a copy on request.

A. M. Byers Co., Pittsburgh, Pa. Established 1864. Boston, New York, Philadelphia, Washington, Chicago, St. Louis, Houston, Seattle, San Francisco.

CORROSION COSTS YOU MORE THAN WROUGHT IRON

GESS—ORIGINATORS OF SNUBBING PRINCIPLE FOR QUIETING DIESEL EXHAUSTS—BURGESS—ORIGIN

BURGESS SNUBBER BULLETIN for Diesel Exhaust Noise Control

A TYPICAL CAUSE OF POOR ENGINE PERFORMANCE

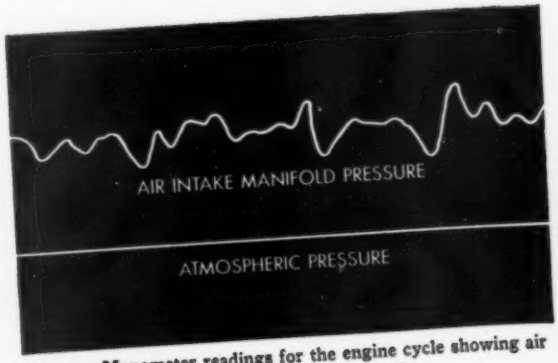
In previous articles we have discussed the effect of the Burgess Snubber on the air intake of a Diesel engine or compressor . . . how the Snubber is used to eliminate resonance, ramming, and pulsations in the air intake system.

Some air intake problems are simple to solve . . . others are particularly knotty, in which case the Burgess engineer is frequently called for consultation and advice.

One interesting problem recently developed in a Diesel electric power plant equipped with a low speed, heavy duty, two-cycle, 10-cylinder Diesel engine with separate scavenging centrifugal blower. Complaints on the installation developed because of a pronounced low frequency pulsation in the air intake of the centrifugal blower. The low frequency pulsation was exactly opposite of what might be normally expected, since the blower speed was 3600 rpm and engine speed only 300 rpm.

The engine was equipped with an oil bath air filter and the pulsations were severe enough to splash oil out of the cleaner oil pan. Also, the audible low frequency sound emitted from the blower intake caused visible vibration of objects adjacent to the filter house.

Before the Burgess engineer was called in, the utility undertook to solve their own problem by installing a second oil bath air filter. This improved the condition only slightly.



Burgess Manometer readings for the engine cycle showing air intake manifold pressure variations.

Burgess manometer tests showed that the pressure fluctuations were having no serious effect on engine scavenging, because the air intake manifold pressure was constantly well above atmospheric pressure. The pulsations, therefore, must be the result of a scavenging condition reflected back through the air intake system.

At the conclusion of the tests, the Burgess engineer suggested the installation of a Burgess Snubber to eliminate the air intake noise and reduce the pulsations in the air intake system.

The Burgess manometer, which records instantaneous pressure fluctuations and provides readings at any point during the engine cycle, has solved many similar air intake and exhaust problems on Diesel engines.

* * *

BURGESS EXHAUST SNUBBER STC SERIES

The STC Series Burgess Snubber is standard for exhaust systems of internal combustion engines, blowers, and vacuum pumps which discharge to atmosphere. The construction of the STC Series Snubber is based on the most advanced knowledge of hydrokinematics of exhaust systems.

The Burgess principle of silencing is based on the theory of "snubbing" the slug of exhaust gas . . . hence the name, Snubber. The slug of fast-moving exhaust gas passes through successive snubbing chambers where the kinetic energy of the exhaust gas is dissipated so that it reaches the atmosphere in a quiet, steady flow. With the Burgess Exhaust Snubber, there is no need to tune the exhaust system to overcome bad exhaust effects.

There is no "second best" Burgess Snubber line. The combination of fine engineering talent and high quality materials can result in only one design and one manufacturing standard. The Burgess STC Series Exhaust Snubbers are constructed of heavy gauge steel and welded throughout to combine strength and lightweight. A typically important Burgess construction detail is the mechanically rigid dome-head construction . . . scientifically correct for the ideal Snubber.

Diesel engine men can do well to investigate the Burgess Snubber line. Burgess engineers will be glad to recommend the correct exhaust Snubber for any engine application.

NEW BOOKLET TELLS A STORY OF SOUND

Diesel engineers and operators of Diesel engines will be interested in reading the new 36-page Burgess-Manning booklet, "A Story of Sound," just released for distribution.

"A Story of Sound" discusses such subjects as: What is sound? What are sound waves? Why are sound waves different? How can we measure sound? What is a sound level? What is a decibel? What does an acoustic engineer do?

"A Story of Sound" is valuable to the Diesel engineer for a better understanding of noise problems. Copies are now available upon request.

Published by BURGESS-MANNING COMPANY Chicago, Illinois

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GESS—ORIGINATORS OF SNUBBING PRINCIPLE FOR QUIETING DIESEL EXHAUSTS—BURGESS—ORIGIN
COMPLETE SATISFACTION IN EXHAUST AND INTAKE QUIETING—SPECIFY BURGESS SNUBBERS—FOR

A Constant Flow

View of one Cell Room at Niagara Plant as interpreted by the artist, Vernon Howe Bailey

TYPICAL of the modern facilities with which Niagara Alkali Company is maintaining a constant flow of electro-chemical products for use in war production is the array of liquid chlorine cells illustrated here. Such up-to-the-minute equipment plus the efficient methods of control over quality established by Niagara's pioneering chemists are responsible to a great extent for Niagara's reputation as a quality producer in this field of chemical manufacture. Niagara's products are the result of thirty-six years of specialization and their reliability represents the untiring efforts of an experienced staff devoted to quality production. Look to Niagara for reliable chemical service.

Niagara ALKALI COMPANY

60 EAST 42nd STREET, NEW YORK 17, N. Y.

CAUSTIC POTASH • CAUSTIC SODA • PARADICHLOROBENZENE • CARBONATE OF POTASH • LIQUID CHLORINE

BUILDERS
WATER AND SEWAGE WORKS
Equipment

A NEW BULLETIN OF TIMELY IMPORTANCE

for

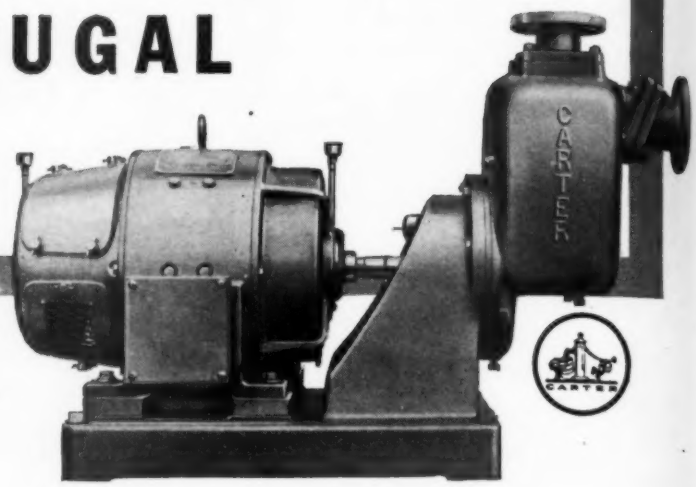
ENGINEERS
SUPERINTENDENTS
OPERATORS

Just off the press, **this entirely rewritten edition of our popular bulletin "Measurement, Control and Chemical Treatment of Sewage and Sludge" has been prepared for engineers and others engaged on sewage treatment problems for both large and small communities. It contains many pages of interesting and valuable information . . . fully illustrated . . . describes new types of indicating, recording and integrating flow instruments devised by Builders engineers for connection to such primary units as Venturi Tubes, Orifices, Kennison Nozzles, Parshall Flumes and Conveyor Scales. Useful reference diagrams are also included. Write today for your copy of Bulletin 287A. Address Builders-Providence, Inc. (Division of Builders Iron Foundry), 10 Codding St., Providence 1, R. I.**

Sincerely

BUILDERS-PROVIDENCE

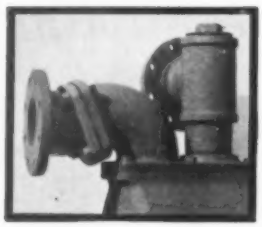
CARTER *Self Priming* CENTRIFUGAL PUMPS



Save Man Hours Save Money

● **Whether it's war or peace, repairing obsolete pumping equipment means dissipating costly man hours. That's money doubly spent when you realize a new unit will deliver more gallonage and give you 100% water insurance with practically no attention.**

For sealing the pumped liquid at the rotating shaft, CARTER provides a stuffing box or seal ring type of seal as illustrated. Both methods are easily maintained, effective and trouble free.



Pump design is such that suction connections can be set to either of the two positions illustrated at right. Modifications of this design are available to suit your particular job requirement.

Built-in suction check eliminates necessity of check or foot valve in suction line. Installed between suction manifold and suction fitting, it is guaranteed to hold vacuum between pumping operations. One of many CARTER features.

Now's the time. "to get set" for those plant improvements you've been thinking about. Whether it's a new installation or a replacement, you'll want the most economical from both the initial and maintenance cost angles. That's where the dependable CARTER unit will prove its merit. That's why thousands of CARTER centrifugal pumps are being used by our armed forces throughout the world.

At home these same pumps cut their eye teeth years ago in the construction field and became nationally famous under the CARTER "Humdinger" trade name. There they proved they could "take it". There they proved that low initial and maintenance costs plus dependability . . . saved man hours and saved money.

● *Write for Bulletin 4310.*

CARTER ALSO MANUFACTURES
DIAPHRAGM PUMPS • SLOW MIXERS
FLOCERS • FLASH MIXERS • CLARIFIERS
PADDLE AERATORS • SLUDGE MIXERS
DIGESTERS • ROTARY DISTRIBUTORS
CONTRACTOR'S PUMPS

RALPH B. CARTER COMPANY

Main Office: HACKENSACK, N. J. New York Office: 53 PARK PL., NEW YORK 7, N.Y.

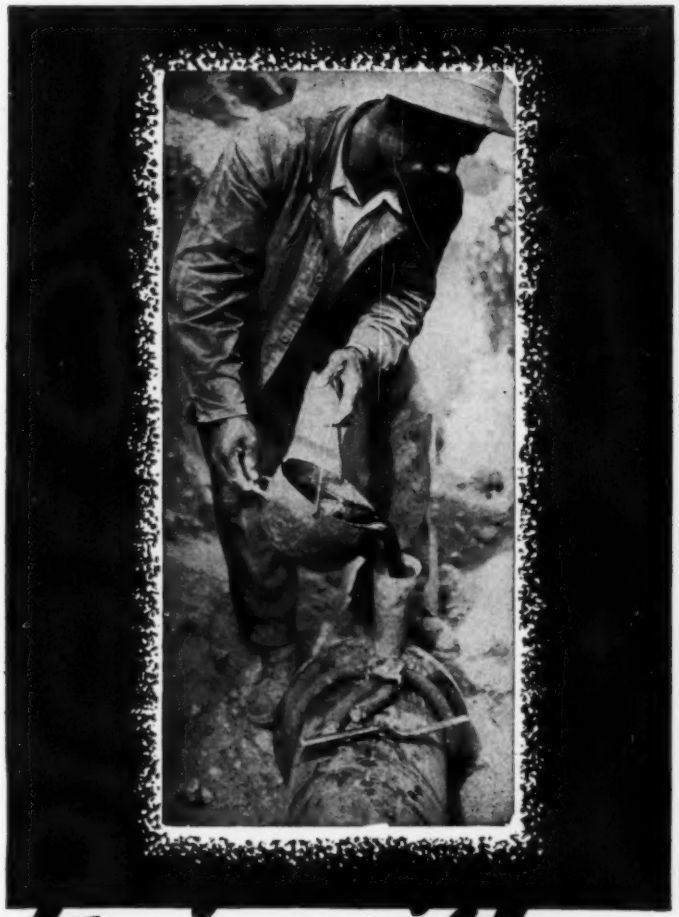
Stop leaks with

HYDRO-TITE

A DEPENDABLE SELF-CAULKING JOINT COMPOUND

Rocco is "pouring for keeps". That HYDRO-TITE joint is a permanent seal for your pipe line. Thousands of users have stuck to HYDRO-TITE for over a quarter of a century because they know that a pipe line is no better than its joints—and the can't afford to gamble. You can be *sure* with HYDRO-TITE.

The Team That Insures Water-Tight Bacteria-Free Joints



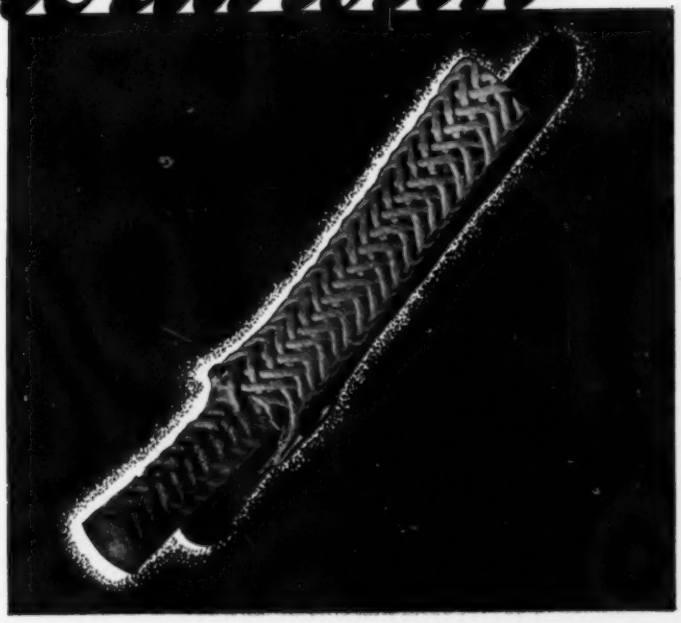
Stop bacteria with

FIBREX

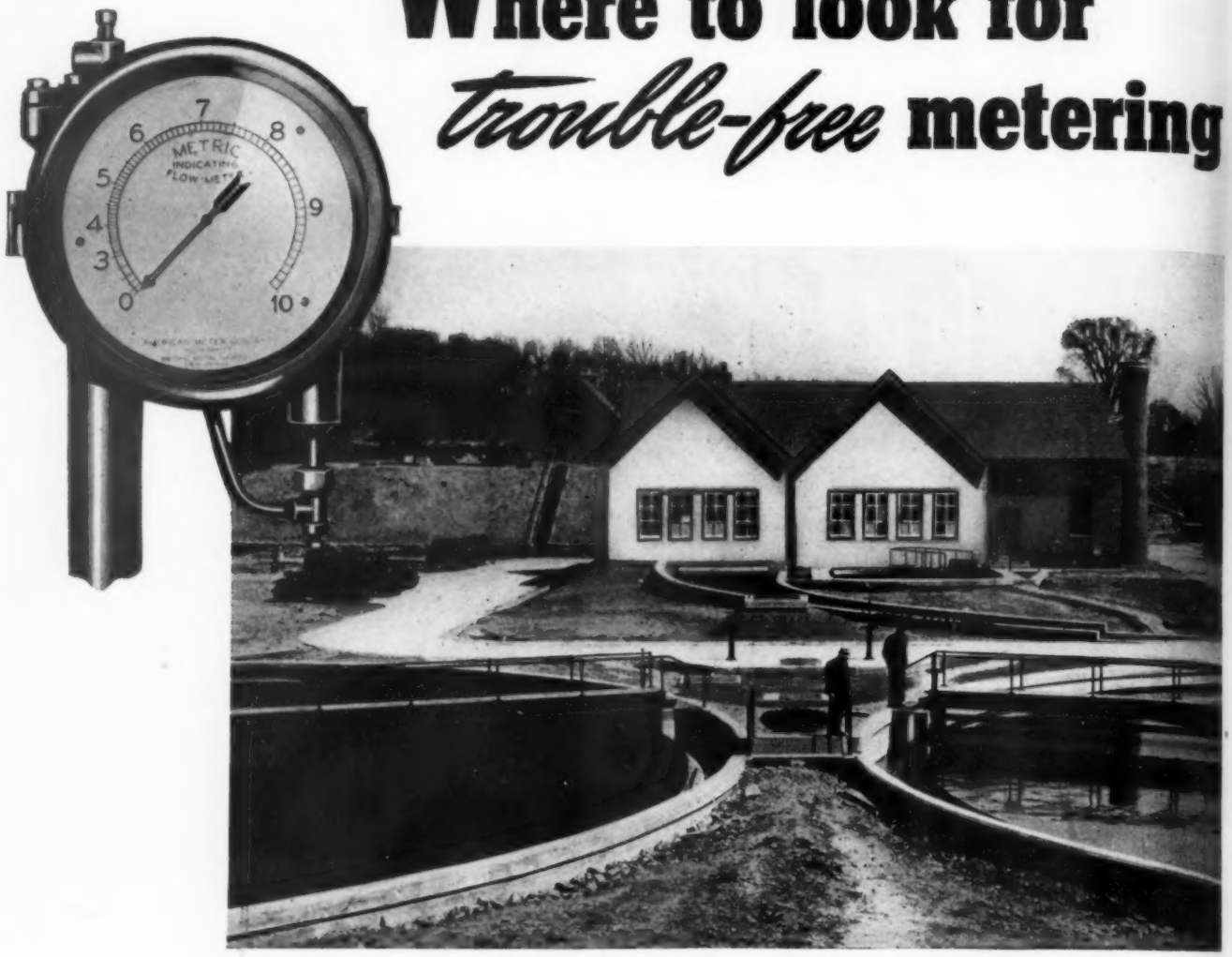
A modern, scientifically developed idea that resulted in a better product than jute. Use it as you would jute; a 60 lb. reel goes almost as far as 100 lbs. of jute. Sample on request.

HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office: 50 CHURCH ST., New York, N. Y.
Works: WEST MEDFORD STATION, Boston, Mass.



Where to look for *trouble-free* metering



• • • Simplicity of basic design is a characteristic of **AMERICAN** meters in both displacement metering of sewage gas and orifice measurement of gases and liquids.

In orifice metering, whether by indicating, recording or integrating instruments, you will find fewer moving parts to wear and get out of adjustment, and every provision for easier inspection. These meters are serving in not only the sewage field and the most modern process industries plants in the country, but in the remote parts of the world where ruggedness and ease of maintenance are of even weightier consequence.

In the field of displacement metering of sewage gas, the **AMERICAN** Ironcase Meter with its rugged one-piece body eliminating gaskets and internal leaks, its full-bellows diaphragm and other features, is giving long years of uninterrupted service.

For consistent trouble-free metering, look to **AMERICAN** simplicity of design.

Descriptive catalogs are available on request.

2186

AMERICAN
METER COMPANY
(INCORPORATED) (ESTABLISHED 1836)
METRIC METAL WORKS • ERIE, PA.

Announcing

NEW ★ COMPACT ★ HEAVY DUTY CLIMAX BLUE STREAK ENGINE

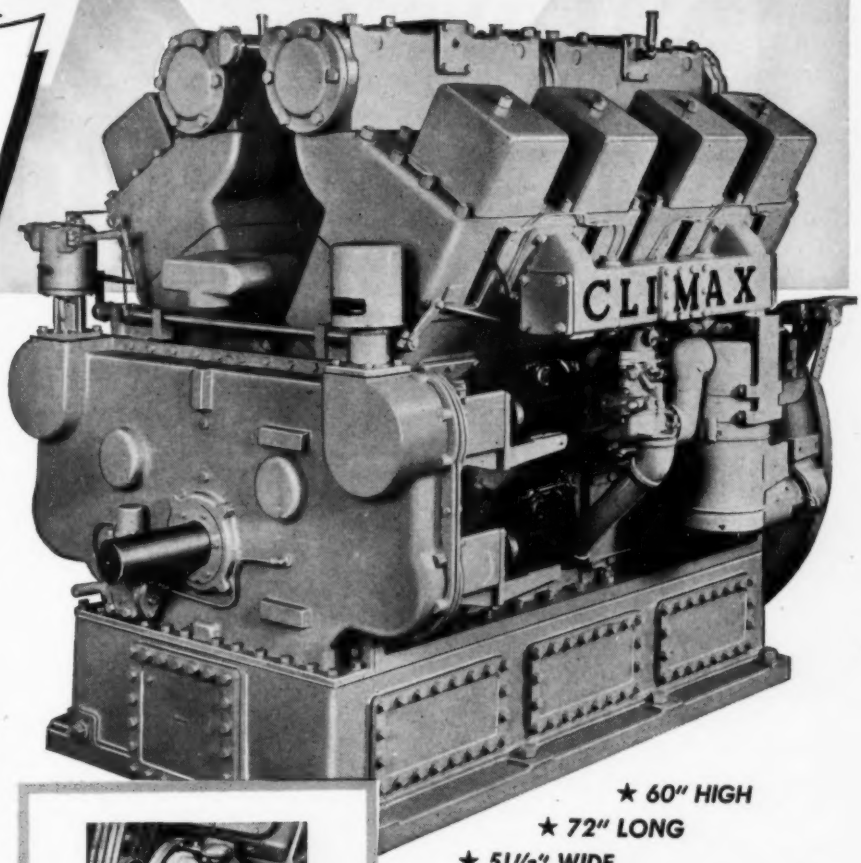
330 h.p. at 1200 r.p.m.

Climax Built-in Extras AT NO EXTRA COST!

1 *Hi-Power Blue Streak Combustion (exclusive).*

2 *Hi-Efficiency Dual Carburetion.*

3 PLUS *Staying Power—the ability to keep on doing the job.*



★ 60" HIGH
★ 72" LONG
★ 51½" WIDE

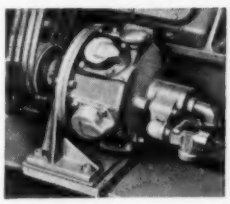
HERE IS BRUTE POWER—in small space—to operate heavy duty mobile or stationary equipment used in oil fields, construction, marine and industrial operations—to power deep-drilling rigs, locomotives, cranes, shovels, boats, generators, air compressors, water and sewage pumps, blowers, etc.

This Climax valve-in-head Blue Streak V8 (8 cylinder, 4 cycle, 7" bore, 60°) Engine is a sturdy, instant-starting, fast-accelerating, smooth-running, flexible prime mover that operates on gasoline, butane, by-product or natural gas. It runs at slow, minimum-wear speeds, at low, safe temperatures in all climates on very little water.

This new V8 promises to sustain Climax Engine records of 7, 9, 10 years' trouble-free service—as much as 60,000 hours of continuous operation with no shutdown for repairs.

For complete operation and specification bulletin, write Climax Engineering Company, Clinton, Iowa.

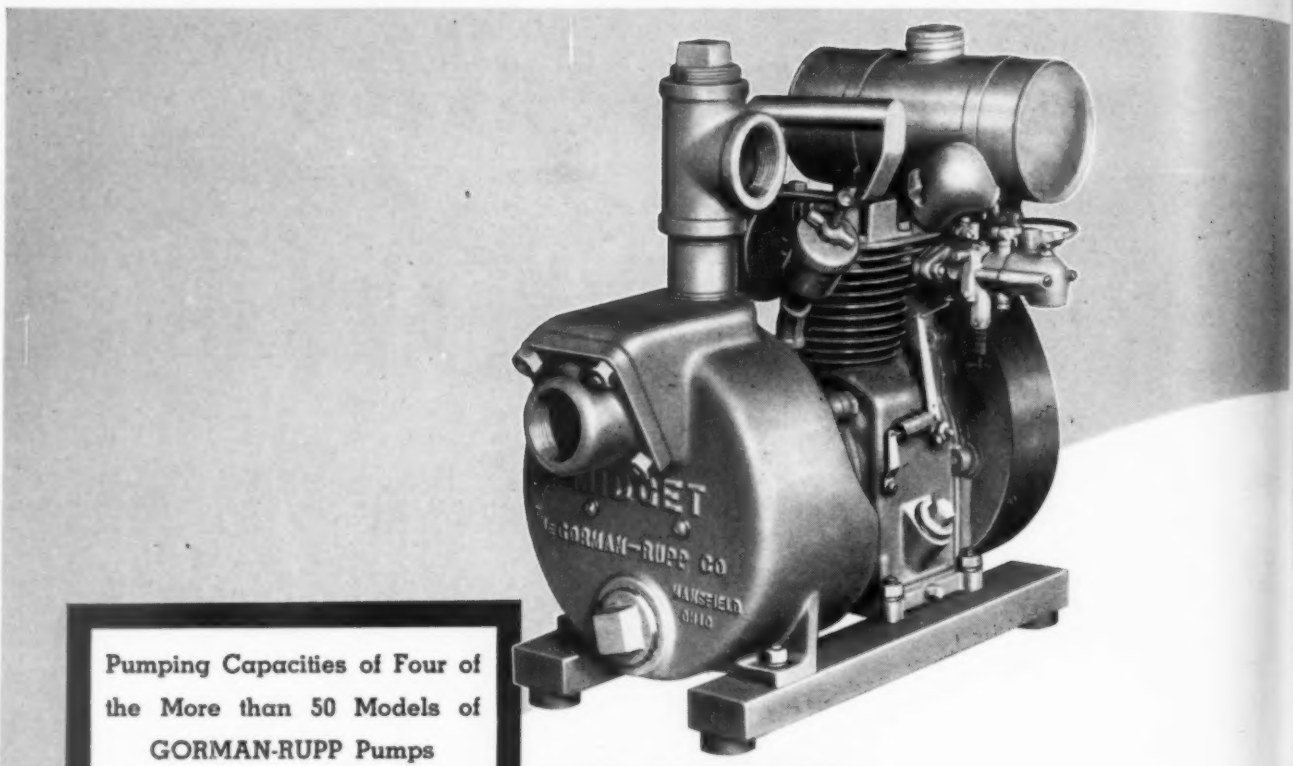
CLIMAX ENGINEERING•COMPANY
General Offices: CLINTON, IOWA
Regional Offices: CHICAGO, DALLAS, FT. WORTH, TULSA



AIR START now available, belt connected or built-in, according to engine size, on all Climax Blue Streak Engines. Choice of air start or gasoline starting optional.

climax
BLUE STREAK ENGINE
Builder of Climax DIESELS and GENERATING SETS

CLIMAX ENGINEERING COMPANY



Pumping Capacities of Four of the More than 50 Models of GORMAN-RUPP Pumps

CAPACITY IN GALS. PER HOUR with pump 15 ft. above water

TOTAL HEAD	MIDGET (60 lbs.)	EAGLE (120 lbs.)	40-M (1080 lbs.)	90-M (1600 lbs.)
25	3360	11220	——	——
30	3180	10200	34500	76800
40	2880	8400	33900	73800
50	2160	6300	32700	69600
60	1500	2700	30600	63000

3000 gallons AN HOUR

AND YOU CAN CARRY IT IN ONE HAND

Pick it up and run it out to any pumping job in a hurry. Start the motor and you start the water -- its fully automatic self-priming. Muck, sand, weeds, solids won't clog or harm it. At average heads it will handle 3,000 gallons per hour, and it will do it a lot of hours without any attention. That's the Gorman-Rupp Midget -- the toughest little pump you ever saw. Anyone can operate it. There are no valves or priming by-passes or other tricks to learn. It's the simplest pump of its kind. The insides are unobstructed and streamlined for high efficiency and non-clogging operation. Here is streamlining where it counts! All this pumping punch comes in only a 60-pound package, complete. It will deliver over six times its own weight of water per minute. Have one or more Gorman-Rupp Midgets ready for any job that may come along.

GORMAN-RUPP PUMPS — ARMY NAVY — UNSURPASSED FOR PUMPING FAST

THE GORMAN-RUPP COMPANY

MANSFIELD • OHIO

"Exceptionally good results"

AT GULF SHORES, FLORIDA, "Aerifier" TREATMENT PLANT

INITIAL OPERATION TEST OF THIS ALL-YEOMANS PACKAGE PLANT MAKES NEWS—

FIVE-DAY B. O. D. 97% REMOVAL

SUSPENDED SOLIDS 98% REMOVAL

UNDIVIDED RESPONSIBILITY

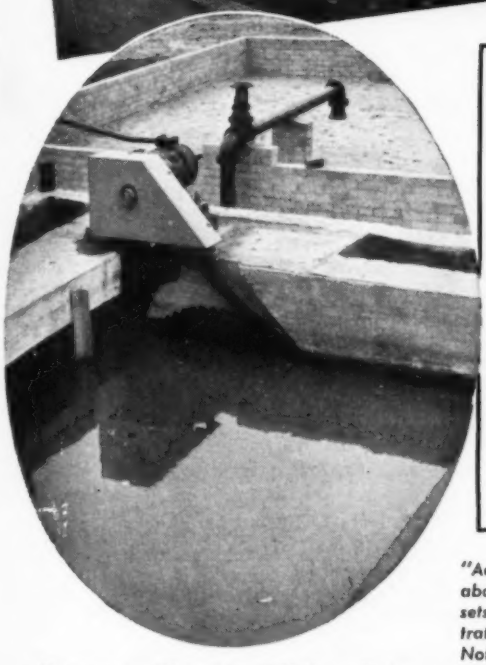
Pronounced "exceptional" and easily exceeding the Yeomans guarantee, this all-Yeomans installation serves a community housing shipyard workers from nearby Panama City.

Heart of the plant is the Yeomans "Aerifier" unit with the Spiralflo aerator, long since distinguished for extraordinary efficiency in the aeration of sewage—and at low power cost. The "Aerifier" combines the processes of aeration and final clarification in one concrete tank.

There are no flies, no odors at this plant, and the all-concrete tank construction means there will be no scraping or painting of steel tanks and baffles to prevent rust and collapse. Nor is a waste sludge hopper required.

Bulletin 6650 gives a complete description of the "Aerifier." Send the coupon for complete information.

Consulting engineers retained by owner for sewerage facilities and sewage treatment plant—Smith and Gillespie, Jacksonville, Florida. Contractor—Paul Smith Construction Company, Tallahassee, Florida.



Yeomans new "Streamline" Sludge collector for rectangular settling tanks is in operation at Gulf Shores. This unit is 20 feet long by 8 feet wide with 7 foot side water depth and is functioning in the primary settling tank.

AN ALL-YEOMANS PLANT

AERIFIER—No. 50 "SPIRALFLO" AERATOR—combines aeration and final settling in one concrete tank.

SLUDGE COLLECTOR—new Yeomans "Streamline" design; 20 ft. long, 8 ft. wide, 7 ft. water depth.

SLUDGE PUMP—YEOMANS No. B1100—40 g.p.m. to 15 ft. T. D. H.

SEWAGE PUMPS AT LIFT STATION—two Yeomans No. 4M3, 100 g.p.m. to 48 ft. T. D. H.

"Aerifier" in operation is viewed from above. The "Spiralflo" aeration cone sets up a spiral movement that penetrates throughout the entire tank. Note the loading funnel which loads the mixed liquor for transfer to the corner settling compartments. The latter can be seen in the lower left and right corners and their quiescent condition assures thorough settling.

Yeomans Brothers Company

1423 NORTH DAYTON STREET
CHICAGO 22, ILLINOIS

YEOMANS PUMPS · GIVE YEOMAN SERVICE ·

Please send Bulletin 6650 describing Yeomans Aerifier.

Name_____

Address_____

Company_____

ANOTHER FIRST IN ENGINE DEVELOPMENT

THE COOPER-BESSEMER SUPERCHARGED GAS ENGINE

For years engineers have sought to develop a practical means of supercharging engines operating on gaseous fuel. This has now been accomplished with complete, unqualified success by Cooper-Bessemer, permitting a 40 to 50 per cent increase in horsepower with no appreciable increase in engine weight or space.

The supercharging is made possible and wholly practical by a simple, patented method of timing the admission of gas, permitting complete scavenging under pressure, without fuel loss.

Obviously, this revolutionary development, particularly when combined with Cooper-Bessemer's recently announced gas diesel, offers remarkable advantages and economies in the sewage and water works field. The cost per horsepower of housing and maintenance is greatly reduced, to say nothing of doing far more work with a given amount of gaseous fuel.

The nearest Cooper-Bessemer office will gladly furnish any additional information you might require on the application of this development to your present or future power needs.

THE COOPER-BESSEMER CORPORATION
Mount Vernon, Ohio Grove City, Pa.

New York Washington Houston Dallas Shreveport Los Angeles
Tulsa St. Louis Seattle Calmes Engineering Co., New Orleans

BUILDERS OF FINE ENGINES FOR 112 YEARS

Sanitation HTH is available in cases of nine 5-lb. cans and in 100-lb. drums.

"Hypo-Chlorination of Water" is a complete reference manual on the use of high-test calcium hypochlorite in the modern practice of safeguarding water supplies. Written in simple, non-technical language, it covers all phases of standard sanitation practice including instructions for emergency use; tables and charts showing quantities of Sanitation HTH required for many specific needs; algae and alkalinity control. Fully illustrated. Many schools have requested copies for student use in courses in water treatment.

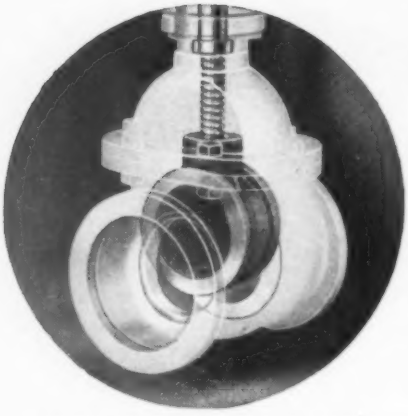
Though more than 25,000 copies—in five editions—have been distributed to those interested in modern water and sewage treatment, Mathieson again offers the latest edition, free of charge, to newcomers in the profession and to those whose copies have "disappeared". Send us a postal card—we'll mail your copy.

P. S. Checked your stocks of Sanitation HTH recently? Remember—in an emergency you'll be glad to have an ample supply on hand.

Mathieson
CHEMICALS

THE MATHIESON ALKALI WORKS (INC.)
60 East 42nd Street, New York 17, N. Y.

Sanitation HTH... Liquid Chlorine... PH-Plus... Fused Alkali... Caustic Soda... Soda Ash... Bicarbonate of Soda... Chlorine Dioxide Ammonia, Anhydrous & Aqua... Dry Ice... Carbonic Gas... Synthetic Salt Cake... Sodium Chlorite Products... Sodium Methylate



LUDLOW DOUBLE DISC GATE VALVES

The parallel seat, double wedge type slide gate valve, developed and perfected by Ludlow, provides a number of essential benefits. For instance:

- *Smooth, Positive Operation.* Gates positioned *directly* opposite ports before wedging, and entirely unwedged *before* being raised.
- *Positive Closure*—even after years of service in the open position; flexible-action gates *self-adjusting* to seats.
- *Self-Cleaning.* Rings cleaned *throughout entire stroke. No internal guides* to cause foul-up.
- *Ready Replacement of Parts.* Simple construction with ample tolerances. permitting ready replacement of parts.

LUDLOW FIRE HYDRANTS

Distinctive List 90. Design now serving in thousands of cities and towns. *No Ludlow Fire Hydrant has ever failed in line of duty!* Employs famous Slide Gate Feature and offers the following advantages:

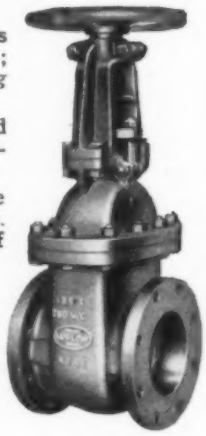
- *Quick Water* with least possible shock. Proper shut-off without water hammer.
- *Proper Drainage.* Hydrant automatically drained at *lowest* point when closed.
- *No Flooding.* Accidental breaking of the hydrant, such as might result by collision from a heavy truck, will not cause flood since the gate when closed is wedge-locked.
- *Easy Inspection and Servicing* without unscrewing anything below the ground level. All working parts removed as one unit by lifting stem through top of hydrant.

LUDLOW EQUIPMENT

Proved by the Past—Fit for the Future

In the last analysis, the best indication of future service in water works equipment is its past record. Through the years — changing systems, higher pressures, lower budgets, wartime emergency— Ludlow Valves, Gates and Hydrants have served efficiently and faithfully. You may continue to rely on them for constant service, low upkeep, resistance to wear and fewer replacements. You may rely, too, on Ludlow engineers to consider your problems their own, making honest recommendations and giving accurate estimates.

Write today for full information



Outside Screw and Yoke Type

← Iron body, bronze mounted—tested at 350 lbs. hydrostatic pressure. List 44—sizes 2″ to 12″—200 lbs. working pressure. List 66—sizes 14″ to 48″—150 lbs. working pressure.

→ Iron body, bronze mounted—complying with latest A. W. W. A. Specifications. Tested at 300 lbs. hydrostatic pressure. Sizes 2″ to 48″.

A.W.W.A. Double Disc Gate Valve

← Iron body, bronze mounted—low pressure valves. List 3 Valves made in sizes 2″ to 48″ and can be furnished with Hub. Flanged. Universal, Spigot, and Screwed Ends.

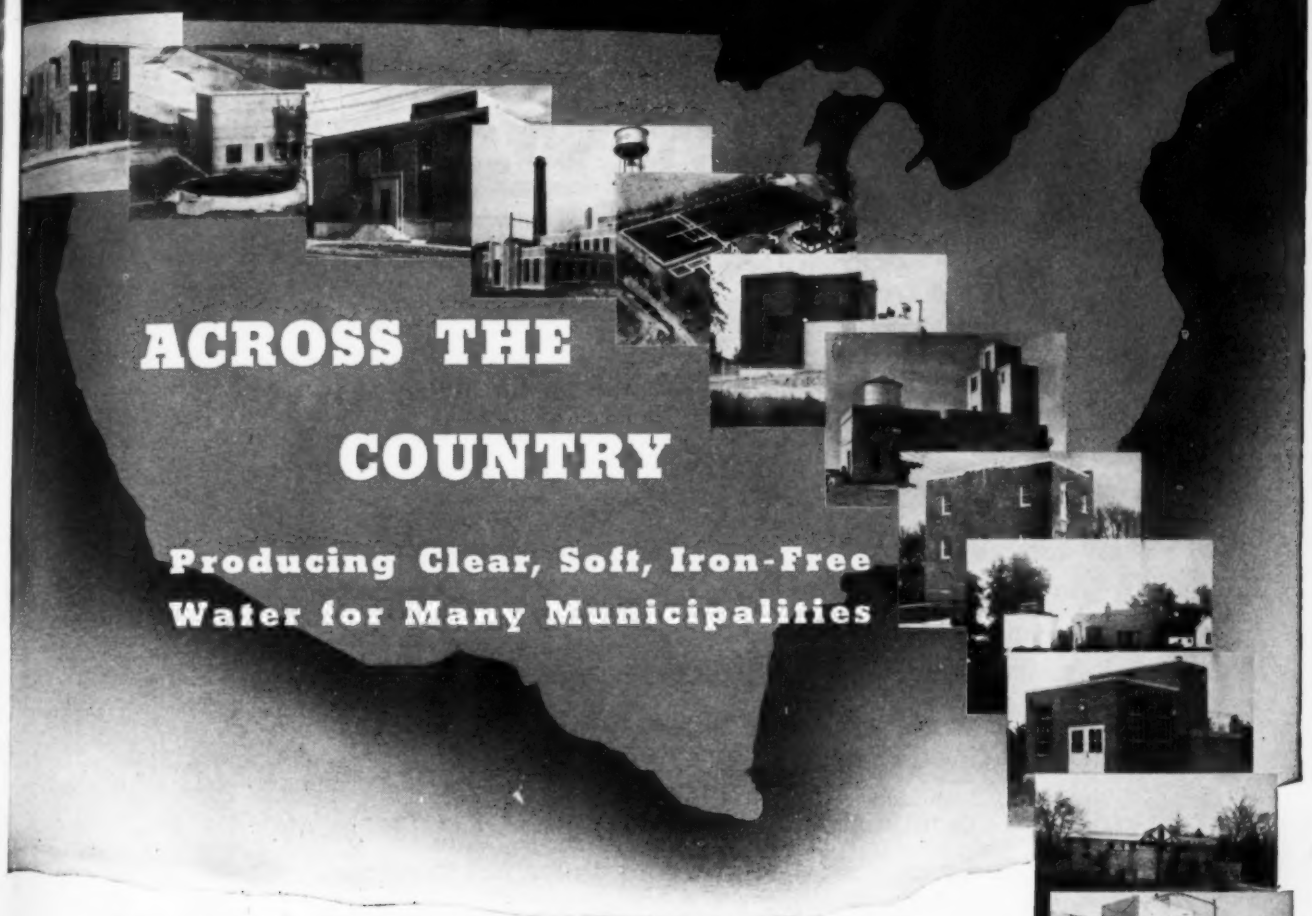
Valve shown with Hub Ends and without gearing. Also available with gearing or outside screw and yoke—and flanged ends.

← Hydraulic Cylinder, iron body, bronze mounted—manufactured in all sizes for any desired test or working pressures. Can be operated by four-way cocks or remotely controlled by solenoid valves.

Flanged End Standard Gate Valve with Cast Iron Bronze Lined Hydraulic Cylinder

The LUDLOW VALVE MFG·CO·INC· TROY·N·Y· SINCE 1866

THERE'S A STRING OF THEM NOW



ACROSS THE COUNTRY

Producing Clear, Soft, Iron-Free Water for Many Municipalities

When it's reconversion time, there will be new materials, methods and ideas to be developed and perfected and molded into useful equipment . . . equipment which eventually will find application in important beneficial Public Works improvements.

In the water conditioning field, however, there is no need to wait for this "miracle" equipment to materialize because

•

ACCELATORS had already gone through the developing and trying-out stage before the war. There's a string of municipal Accelator installations across the country now.

ACCELATORS are doing a lot of different things for a lot of different kinds of water...clarifying...softening...stabilizing . . . removing color . . . taking out iron.

Results are always excellent . . . frequently remarkable.

You can't beat ACCELATORS for Performance and Economy. Would you like Bulletin 1824?

INFILCO

INCORPORATED

325 W. 25th PLACE, CHICAGO 16, ILL.

ZECO and HI-ZECO Greensand Zeolite for water softening, filtration and iron removal. ZECO Manganese Zeolite for iron and manganese removal. COREXITE mineral for corrosion control and water stabilization.

★

ZEOLITE CHEMICAL CO.

Sales Office
140 Cedar St., New York, N. Y.

Factory
Medford, N. J.

Pioneer Producer of GREENSAND ZEOLITE MINERAL

Fine instruments since 1907

LEUPOLD & STEVENS INSTRUMENTS

Nearly forty years ago a man decided to make very fine mechanical measuring instruments. His name was Fred Leupold. He began business the hard way. Limited capital, limited market. He had two vital assets—an extraordinary sense of perfection in things mechanical, and a fixed resolve to make only the best.

That was in 1907 in Portland, Oregon. Fred Leupold and his first partner, Adam Volpel, have passed on. They did their work well, for their products are used around the world . . . Out of four decades of specialization in their exact art has come a line of measuring instruments that engineers respect and cherish.

Three times in these forty years the firm has had to move to larger quarters. Still further expansion in plant facilities and equipment is inevitable. For the firm—now known as Leupold & Stevens Instruments—is hip-deep in the manufacture of instruments for the armed services, for civil engineers, and in the development of advanced instruments to meet the demands of peace.

Leupold & Stevens Instruments will not be unknown to you, but the extent of the line will perhaps be newsworthy and of value in your work. Write for Bulletin No. 23 in which illustrations and descriptions are given of instruments—surveying, hydrographic, navigation. Your bulletin will come by return mail with our compliments.

LEUPOLD & STEVENS INSTRUMENTS

MANUFACTURERS SINCE 1907

PORTLAND 13, OREGON

Hydrographic, Surveying, Navigation, Automatic Controls

Leupold & Stevens Instruments
4445 N. E. Glisan Street, Portland 13, Oregon
Please send Bulletin No. 23 illustrating and describing your instruments.

Name _____

Organization _____

Title _____

Street _____

City _____ *Zone* _____ *State* _____

UNDIVIDED RESPONSIBILITY

THE PROBLEM

When considering the installation of new equipment for your water works or sewage plants you are concerned with the ultimate operation of the plant as a unit, and therefore should consider the value of having the various pieces of equipment installed by a single contractor fully experienced in the problems of installation, operation and servicing of each piece of apparatus.

THE SOLUTION

Our 37 years of experience as equipment contractors in the water works and sewage field qualify us to undertake the installation, placing in operation and servicing of all of the mechanical and electrical equipment for your plant, including interconnecting piping and wiring and all auxiliary items such as meters, instruments, etc., and to assume the full and undivided responsibility for operation of all component pieces of apparatus as a unit.

TURBINE EQUIPMENT COMPANY

75 WEST STREET NEW YORK 6, N. Y.

REPRESENTING AND SERVICING

DE LAVAL STEAM TURBINE CO.
DE LAVAL SEPARATOR CO.

PEERLESS PUMP CO.
YEOMANS BROS. CO.

COCHRANE CORP.

WHEN LIFE HANGS BY A THREAD!

Remove the nozzle-cap . . . couple-up the hose . . . turn the operating-nut. Lives hang by a thread in all these operations. And in Mathews hydrants, the threads, whether standard or specially made for your needs, are designed and manufactured for dependability. For more than seventy years, every feature of the Mathews design, from operating-nut shield at top to bronze elbow-bushing at bottom, has been consistently developed and improved. Today, more than 400,000 Mathews hydrants in all climates and countries testify to the reliability of the design, the correctness of the manufacture. For long life, low maintenance, and for quick, sure operation when lives depend upon it, specify Mathews for your community.

MANUFACTURERS OF SAND SPUN PIPE (CENTRIFUGALLY CAST IN SAND MOLDS) AND R. D. WOOD GATE VALVES

NOW pipes as small as 30 inches

30" Lining Machine leaving a pipeline that has just been Centrilined

. . . . reconditioned by Centriline

Here's good news! If the diameter of your pipeline is 30" or more . . . whatever its length . . . wherever situated —Centriline men and equipment can quickly reach and recondition it.

The Centriline process is a rapid and economical method of reconditioning pipelines. It consists of cleaning the main and applying by centrifugal force, a dense cement mortar lining of required thickness, mechanically troweled to a smooth finish. This new coating will permanently resist the invasion of tuberculation and corrosion—and will restore and maintain a high carrying capacity.

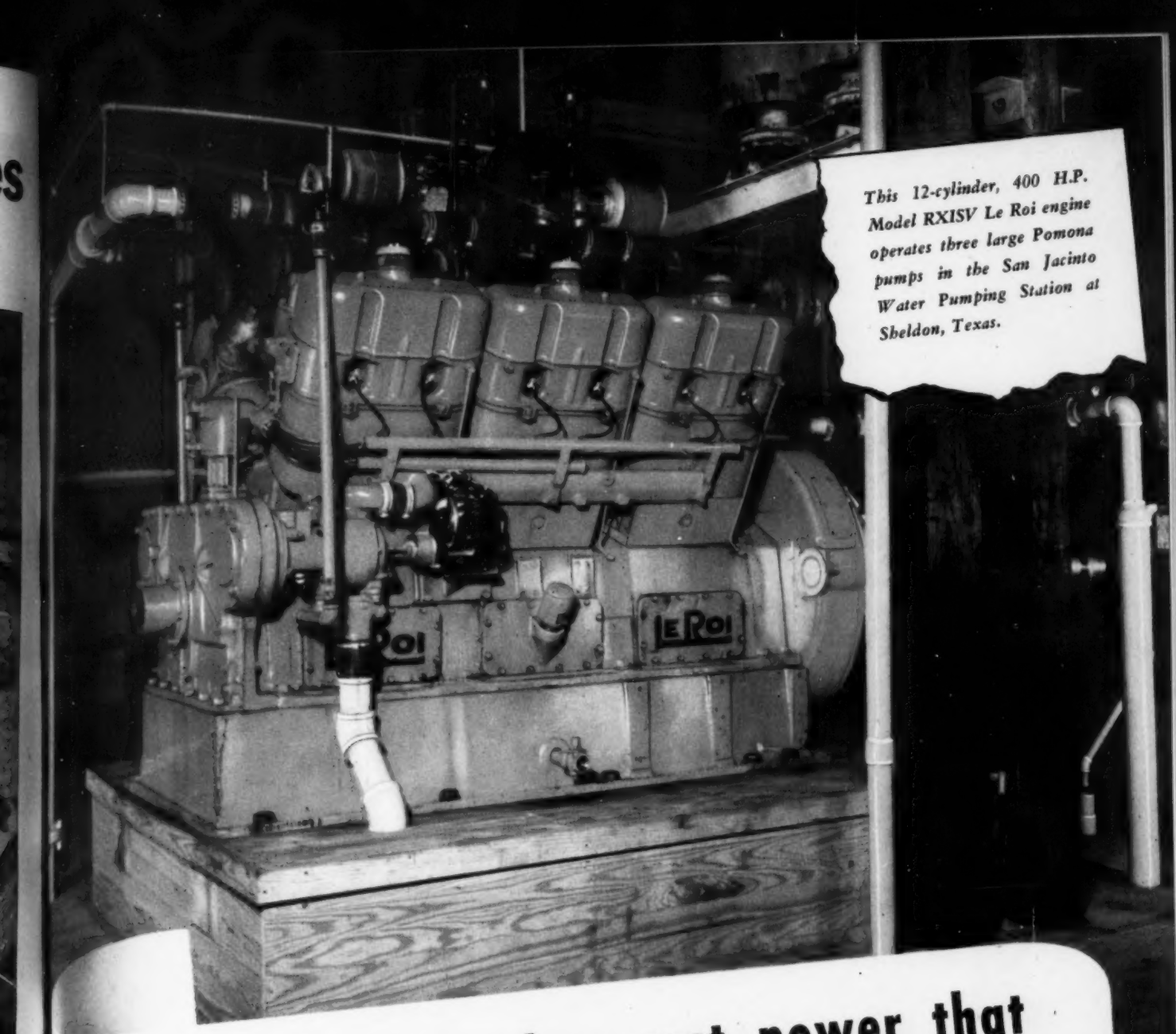
Don't wait until it's too late . . . let Centriline clean and re-line your pipelines now. In that way you'll safeguard your initial investment.

The sleek new lining of a pipe that has been Centrilined

CENTRILINE CORPORATION

148 CEDAR STREET, NEW YORK 6, NEW YORK

Restores and Protects Pipe-Line Carrying Capacity



This 12-cylinder, 400 H.P. Model RXISV Le Roi engine operates three large Pomona pumps in the San Jacinto Water Pumping Station at Sheldon, Texas.

For dependable, low-cost power that backs up your good judgment, insist on LE ROI ENGINES

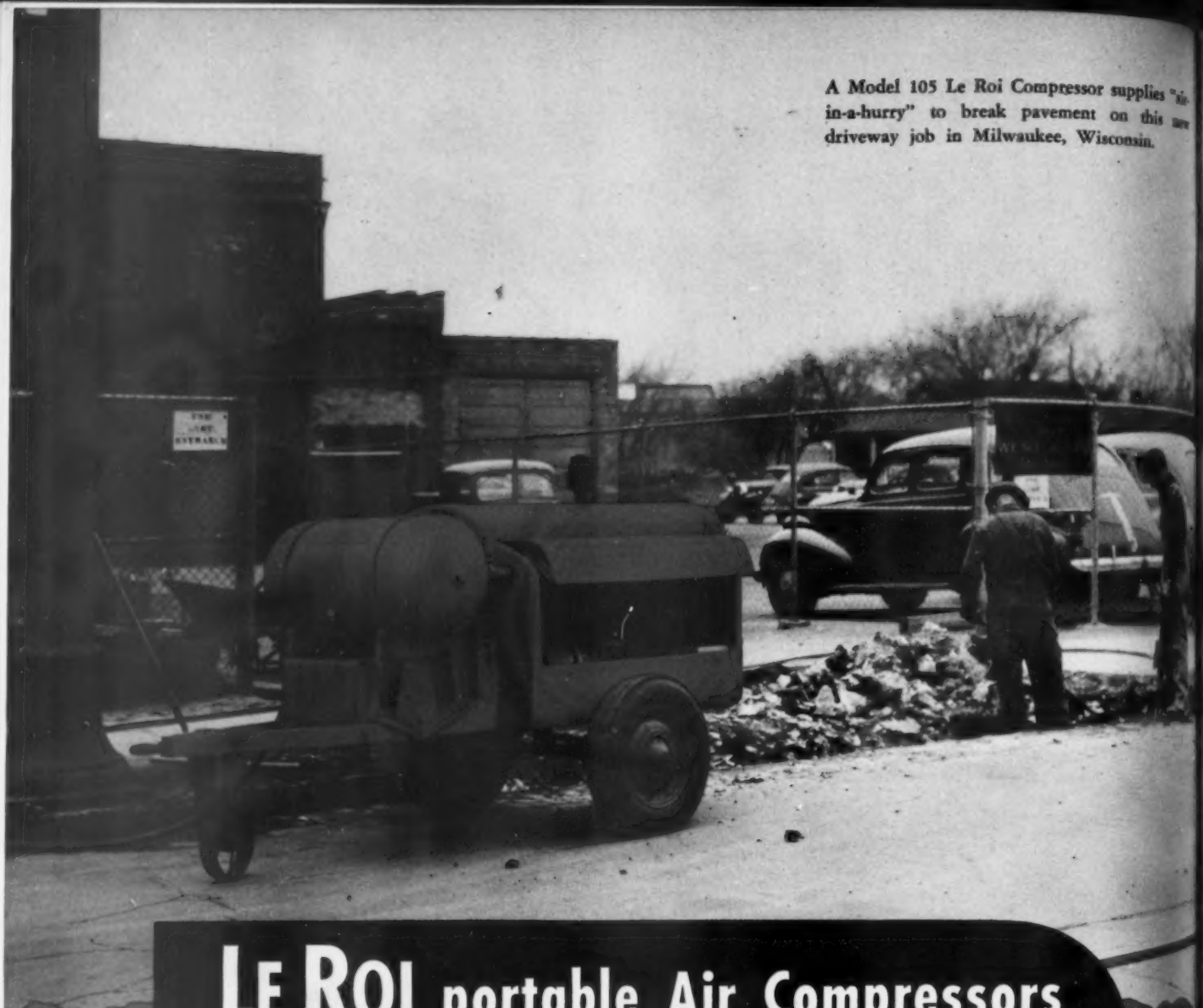
In municipal service, Le Roi engines have won the praise of men who are responsible for the unfailing operation of their equipment. One of the underlying reasons for the thoroughly dependable operation of Le Roi engines is the fact that they are built by a manufacturer *concentrating exclusively* on the problems of the heavy-duty field. Le Roi engines have the weight and stamina to take the punishment of continuous operation without costly breakdowns. They have the quality features that give you more for your money — precision machining that gives you smooth operation — reserve power that carries you over the heavy loads.

When you specify "Le Roi" engines, your recommendation is backed by many years of experience in the specialized power requirements of your particular field.

Write for Complete Information.

LE ROI
MILWAUKEE

TURN THE PAGE



A Model 105 Le Roi Compressor supplies "air-in-a-hurry" to break pavement on this new driveway job in Milwaukee, Wisconsin.

LE ROI portable Air Compressors help you beat "completion" dates . .

by performing dependably when the going is tough

When you need air in a hurry to complete a job before the contract date, depend on a Le Roi Compressor to see you through. It asks no favors or pampering on the toughest kind of jobs.

Because this compressor is the only one in which both engine and compressor are built by the same manufacturer, you get the benefit of: (1) Coordinated action for greater smoothness and efficiency. (2) Low maintenance cost and long life, because BOTH are built to the precision standards of a leading engine builder. (3) Undivided responsibility for performance and service.

Every detail in engine and compressor has been engineered to give you dependable performance. Le Roi Compressors are available in sizes from 60 to 500 c.f.m., gasoline or Diesel powered, on mountings designed to fit your particular needs.

Le Roi distributors are located in key cities throughout the United States and Canada.

Bulletins available — write for them today.

LE ROI COMPANY • 1726 S. 68th St., Milwaukee 14, Wisconsin

LE ROI
MILWAUKEE

SIMPLEX VENTURI TUBES

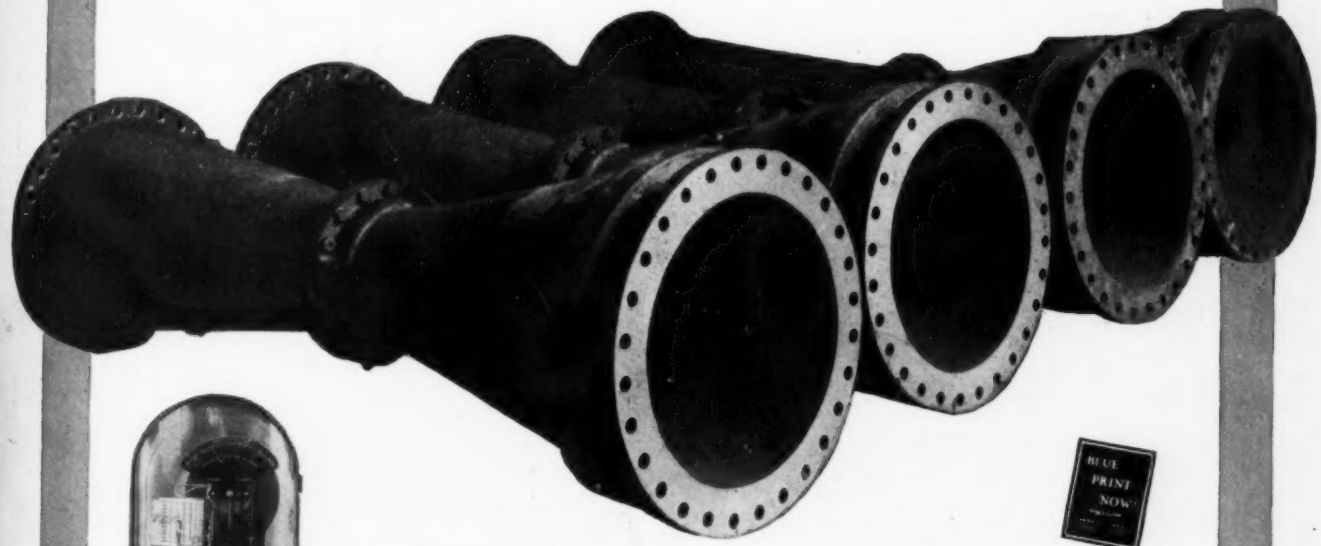
the ULTIMATE IN *Venturi Efficiency*

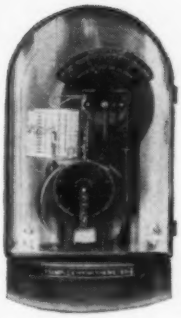
For a given flow of water, the Simplex Venturi and its Simplex Meter will measure with the least loss of energy, and the greatest accuracy over the widest range of flow!

The high constant efficiency with which the Simplex Venturi utilizes the differential head which it creates, has been proved by over 40 years of research and manufacture.

This highly-engineered primary device assures minimum head loss and normal, dependable coefficients. The unit is homologous in type and form; the tube throat is bronze-lined with extremely accurate piezometer taps; the pressure belt type design is essential to high and unvarying accuracy.

The venturi tube is accepted as being the most efficient of primary devices. . . . Installations as part of pipes and conduits of cast material and of fabricated structure, have proved the Simplex Venturi to be unsurpassed in installed operating efficiency!





THE MO METER COMPLETES THE PICTURE

The "MO" is the "Master" Meter that converts the differential head created by the Simplex Venturi into rates of flow and indicates, records, and totalizes that flow with the maximum overall accuracy. This combination of Simplex primary device and MO Meter provides a standard of operating efficiency for the flow measurement of water, sewage and process liquids ni many municipal and industrial plants. The MO Meter is of such high accuracy that it may be utilized for testing the accuracy of other metering equipment. Write for Bulletin 300 — "The Simplex MO Meter."

SIMPLEX VALVE & METER CO.
6743 UPLAND STREET, PHILADELPHIA 42, PENNA.

SMITH VALVES AND HYDRANTS *Available NOW!*
for Maintenance NEEDED NOW!

Recognizing the *necessity* for adequate maintenance of the nation's water supply systems, the W.P.B. has, since the beginning of the war, authorized the production of certain needed water works materials, including valves, hydrants and maintenance equipment. Thanks to this farsighted policy, the A. P. Smith Manufacturing Company is now in a position to offer prompt shipment of:

FIRE HYDRANTS

GATE VALVES

TAPPING SLEEVES and VALVES

And other Smith water works equipment

There's no reason to let your system run down or to deny adequate service and protection to the communities you serve. Do your needed maintenance work now and take advantage of the availability of Smith products.

FIRE HYDRANTS
GATE VALVES
CHECK VALVES
INSERTING VALVES
TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

FLOOR STANDS
INDICATOR POSTS
TAPPING MACHINES
INSERTING MACHINES
PIPE CUTTING MACHINES
CORPORATION TAPPING MACHINES

When Johnny comes home to stay.....

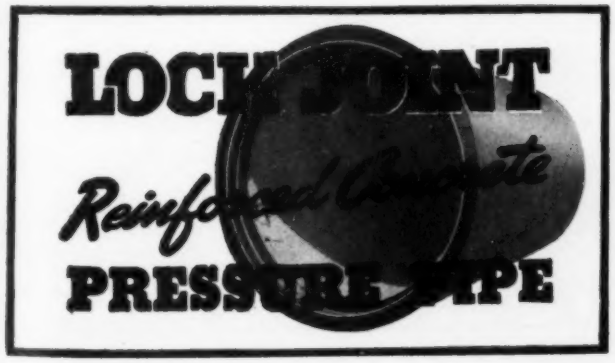
GIVE HIM PLENTY OF BIG JOBS TO DO

RIGHT NOW, on the home front, it's up to city officials and leading engineers to do their part in planning new municipal water mains and other public works projects. It's one way to have steady employment ready for local men when their present job is finished.

By specifying Lock Joint Reinforced Concrete Pressure Pipe for water supply lines, sewerage and drainage, you can fulfill your promise to your own returning men. For, the Lock Joint Pipe Company is prepared to come to your town, set up a temporary plant and employ 90% of local labor. As most of the supplies and materials will be purchased locally, there will be a direct benefit to your town merchants. As a result, a large proportion of the cost of the project will be spent right in your own community.

For more than three decades Lock Joint Pipe has played a vital part in the majority of large diameter water pipe contracts in the United States. When Victory comes, we stand ready to help you give your engineers, mechanics, carpenters, laborers and other skilled workers the jobs they will need.

Whether your project is large or small, for the present or the future, your 'phone call, telegram, cable or letter to any of our offices will bring a prompt reply.



LOCK JOINT PIPE COMPANY

Established 1905

AMPERE, NEW JERSEY

Denver, Colo. • Chicago, Ill. • Kenilworth, N. J. • Kansas City, Mo. • Rock Island, Ill. Joplin, Mo. • Valley Park, Mo. • Cleveland, Ohio • Hartford, Conn. • Navarre, Ohio

SCOPE OF SERVICES *Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply Mains as well as Concrete Pipe of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous lines.*

MONO-CAST CENTRIFUGAL PIPE

with Joints for Every Service Condition

36-inch sanitary sewer line with Doublex Simplex Joints at Corpus Christi, Texas, before backfilling.

Corrosion-resisting Mono-Cast Centrifugal Pipe can be supplied with joints for conveying gas, oil, water and other liquids under every service condition. In most cases, these joints can be made up with unskilled labor and without special tools. Among the joints available are:

- **Standard Bell-and-Spigot**
- **Doublex Simplex**
- **Roll-on-Rubber Ring**
- **Screw Gland**
- **Molox Ball-and-Socket**

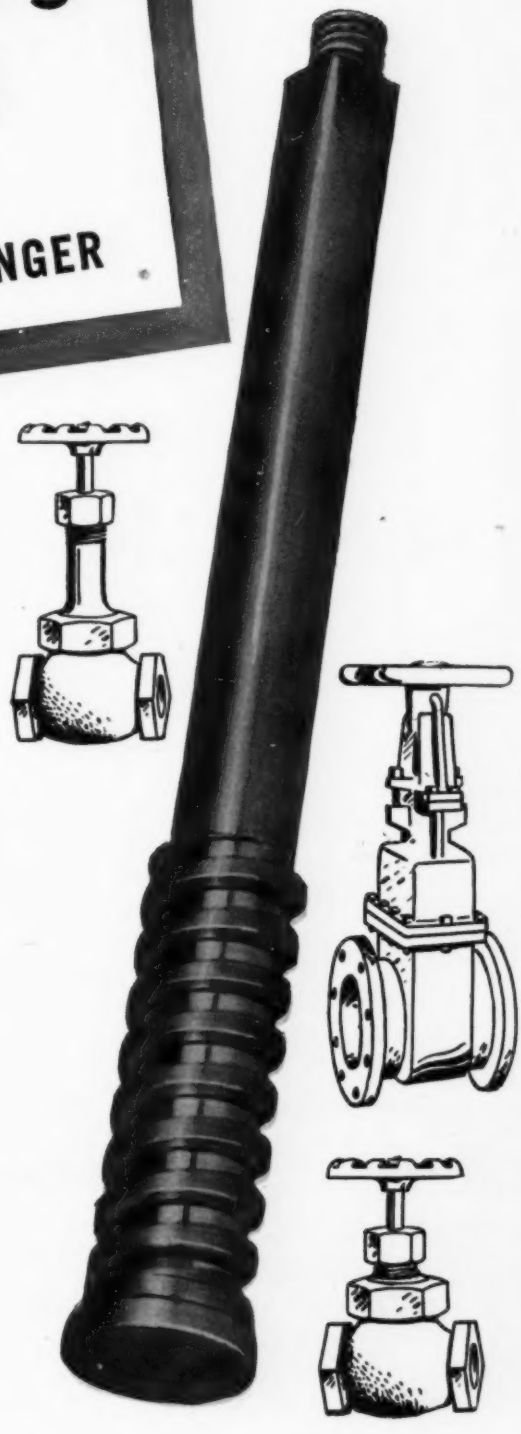
Mono-Cast Centrifugal Pipe is also supplied with either cement or Enameline lining (prevents tuberculation) and with armored coating for use in vicious soil conditions. State the conditions under which the pipe is to be used and we will gladly make recommendations.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM 2, ALABAMA

CHICAGO NEW YORK CLEVELAND
DALLAS PITTSBURGH HOUSTON
EL PASO KANSAS CITY LOS ANGELES
MINNEAPOLIS SAN FRANCISCO

PRODUCT IMPROVEMENT THROUGH BRIDGEPORT'S DURONZE ALLOYS MAKING VALVES LAST LONGER



No product is better than its most vulnerable part. In the case of valves, the stems are generally the first to fail because of corrosion or wear. Why should a superbly designed product suffer because of inferior materials?

Alert designers and engineers are preventing premature failures by changing their metal specifications—selecting Duronze to replace less dependable metals. Some metals still in use have been made obsolete because of the new and better engineering alloys resulting from Bridgeport's research and development program.

Bridgeport's Duronze III is a modern engineering alloy of exceptional merit. It is a silicon aluminum bronze which has a tensile strength of about 90,000 pounds per square inch in its annealed condition; is 9% lighter in weight than brass; possesses a low coefficient of friction; resists wear and stress corrosion cracking. It withstands corrosion better than most metals and naturally it does not dezincify. It machines from 50% to 70% as fast as free cutting brass rod. It is ideal for screw machine items such as valve bushings and seats, pump parts, bolts and nuts, oil burner nozzles, wire and cable connectors, marine hardware and many others.

In water works and sewerage plants where equipment must withstand treated water, acids, corrosive liquids and gases, parts made from Duronze outlast ordinary materials. Write for 80-page Duronze Manual containing suggested applications and latest specifications.

BRIDGEPORT BRASS COMPANY
BRIDGEPORT 2, CONN.
Established 1865

Duronze Alloys—PRODUCTS OF
BRIDGEPORT BRASS

TEN REQUIREMENTS
FOR UNDERGROUND MAINS
under normal conditions

Long Life: In evaluating bids, the useful life of cast iron pipe is figured at 100 years minimum.

Carrying Capacity: The carrying capacity of standard tar-coated cast iron pipe remains practically unimpaired for centuries. For the certain areas where tuberculating water is encountered, cement-lined cast iron pipe is available. Under such conditions, no other material offers the combined long life and sustained carrying capacity of cement-lined cast iron pipe.

Tight Joints: For *ordinary* pressures, cast iron bell-and-spigot pipe—for *high* pressures, cast iron mechanical joint pipe—are known to be leak-proof.

Tensile Strength: When tested under hydrostatic pressure to destruction, the ultimate tensile strength of cast iron pipe is a minimum of 11,000 p.s.i. for pit cast pipe and a minimum of 18,000 p.s.i. for cast iron pipe made by other methods.

Beam Strength: Under beam stress tests, 10 ft. span, standard 6" cast iron pipe sustains a load of 15,000 pounds and bends approximately one inch before breaking.

Toughness: Under hydrostatic pressure and the impact of a 50 lb. hammer, standard 6" cast iron pipe does not crack until the hammer is dropped four feet.

Internal Pressure: An average of many internal hydrostatic pressure tests on standard 6" cast iron pipe shows this pipe withstands more than 2500 pounds pressure per square inch.

External Load: In regulation ring compression tests, standard 6" cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

Imperviousness: The walls of cast iron pipe are impervious to leakage, seepage, or sweating of water, gas or chemicals under internal pressure tests.

Tapping: Cast iron pipe can be tapped cleanly with strong, tough threads, losing little in structural strength.

Other pipe materials meet some of these requirements but only cast iron pipe meets them all.

Whether a pipe material is able to fulfill these requirements is a matter of experience rather than prediction. A page of history is worth a volume of sales claims. History proves that cast iron pipe has been meeting these ten requirements for generations.

Cast Iron Pipe Research Association, Thomas F. Wolfe, Research Engineer, Peoples Gas Building, Chicago 3.

CAST IRON PIPE
SERVES FOR CENTURIES

CAST IRON

Report by the Army

Hexametaphosphate treatment has been used satisfactorily at ninety-two posts

The Army wants its hot water hot — 180°F. minimum is specified for washing dishes. Heaters operating at the higher levels necessary to deliver water in the mess halls at this temperature naturally scaled up or corroded out at an extreme rate.

Post engineers seeking an answer to their mounting difficulties back in 1941 turned to Calgon* for help. Simple and straightforward treatment with a few pounds of Calgon kept heaters on the line continuously for many months instead of a few days, cut down losses of critical equipment at a time when every pound of metal was precious.

Now the Army in a recent survey of its installations in this country, finds 92 posts where Calgon is relied upon to do at least one of the three jobs it does so effectively:

1. *Prevent scale*
2. *Prevent "red water"*
3. *Control corrosion*

Calgon pioneered these developments. Today, in war industry, as in Army camps, unadulterated Calgon made from food-grade phosphoric acid is doing an outstanding job in solving water problems.

**Calgon is the registered trade-mark of Calgon, Inc., for its glassy sodium phosphate products.*

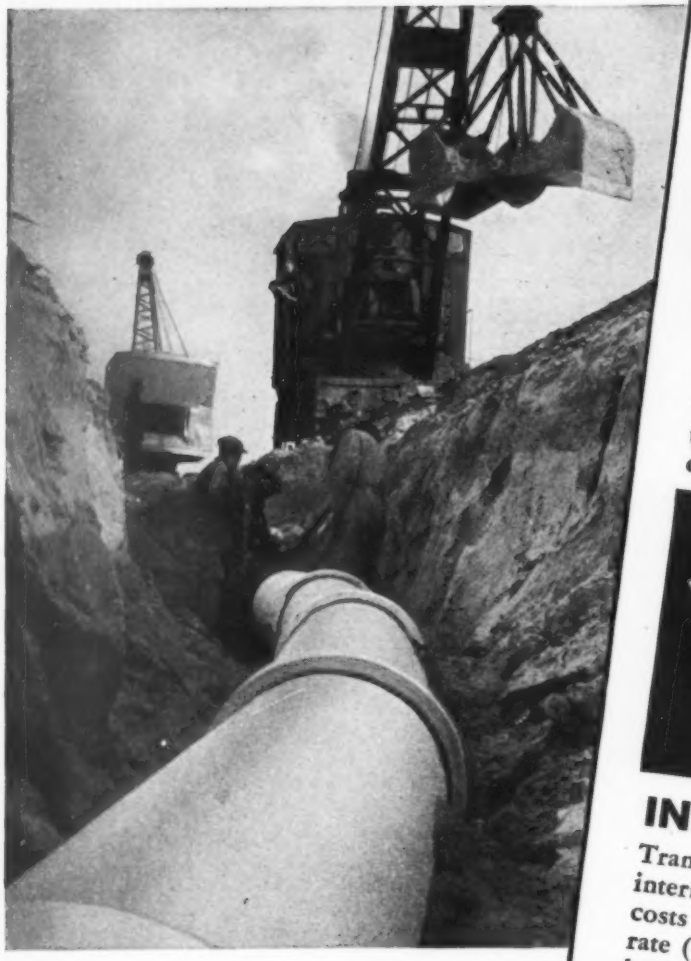
HAGAN
HALL
BUROMIN
CALGON

calgon, inc.

A SUBSIDIARY OF
HAGAN CORPORATION

HAGAN BUILDING
PITTSBURGH 30, PA.

IT *RESISTS* CORROSION

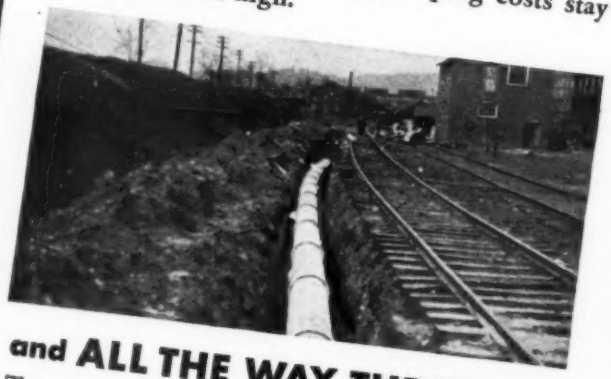


OUTSIDE

Transite Pipe is stubbornly resistant to soil corrosion. Thousands of successful installations, many of them in highly corrosive soils, testify to its stability under a wide range of service conditions.

INSIDE

Transite Pipe cannot tuberculate. This costly internal corrosion that increases maintenance costs can never choke off its initial high flow rate (C=140). As a result, pumping costs stay low, pressures high.



and ALL THE WAY THROUGH

Transite Pipe resists destructive attack. Made of asbestos and cement bonded together under great pressure, its ability to provide efficient, economical water transportation has been proved in thousands of installations.

EASY HANDLING is an additional advantage of Transite Pipe. Its light weight means more footage carried per truck load, fewer men required for handling, lower transportation costs. And in the trench, the Simplex Coupling assures quick, easy assembly, even with inexperienced crews.

For full details, write Johns-Manville, 22 East 40th Street, New York 16, N. Y.

Johns-Manville **TRANSITE PIPE**

FOR EFFICIENT, ECONOMICAL WATER TRANSPORTATION

ALOXITE POROUS UNDERDRAINS FIRST CHOICE - *Coast-to-Coast*

Since their introduction in 1935, more than 100 "ALOXITE" porous plate underdrain installations have been made in 22 states and in a number of foreign countries. These are large and small, gravity and pressure, municipal and industrial, operating under all sorts of conditions and handling all kinds of water. Their record speaks for the soundness and simplicity of the idea.

In service, "ALOXITE" ceramically bonded aluminum oxide plates carry the filter media directly, eliminating all graded gravel. Back wash is complete and uniform—often requiring less water than other systems. Filtering and backwash operating heads are reduced.

The "ALOXITE" underdrain system does not require new structures—it can be fitted into existing filters with the same benefits obtained from new units.

Our technical staff will be glad to discuss the advantages of the "ALOXITE" porous underdrain system for your particular problem. Write The Carborundum Company, Refractories Division, Dept. W-4, Perth Amboy, N. J.

"CARBORUNDUM" and "ALOXITE" are registered trade marks of, and indicate manufacture by, The Carborundum Company.

Porous Products by CARBORUNDUM
TRADE MARK

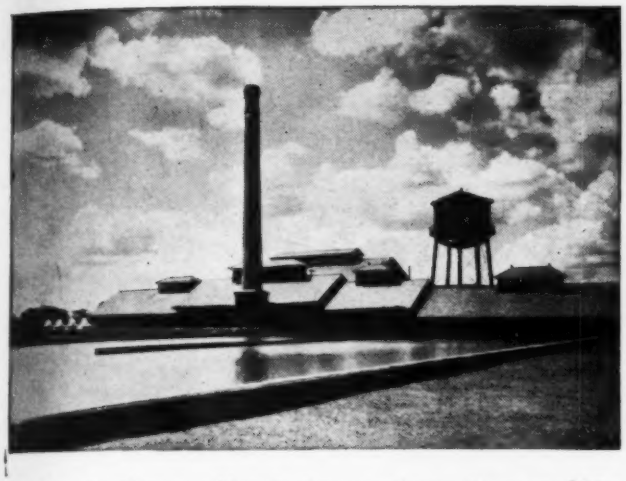
Lithographed on stone by Edward A. Wilson

Illustration shows installation of cast iron flexible joint subaqueous pipe line specified for the required service conditions. How to do it when you get the go-ahead is a problem we are always glad to help out on if it involves pipe design, or recommendations as to pipe and fittings which have successfully met similar problems. To see that our product is correctly specified for the purpose intended is an important function of our sales engineering and technical staffs. Forty-five years' experience as largest producers of cast iron pipe is behind them and always at your service.

U.S.
cast iron
PIPE

U. S. PIPE & FOUNDRY CO.
General Offices: Burlington, N. J.
Plants and Sales Offices throughout the U. S. A.

GENERAL CHEMICAL "ALUM"
... EQUALLY EFFICIENT FOR COAGULATION OF *WATER and SEWAGE!*



Today, aluminum sulfate is almost universally accepted by water experts as the best coagulant for the removal of turbidity, color and bacteria from water . . . and General Chemical Aluminum Sulfate is the outstanding choice the nation over. The reason? Operating men have come to rely on its high quality and constant uniformity, knowing that the effectiveness of General Chemical Alum has been "proved in settling basins all over America."

Municipal officials in charge of sewage disposal find that clarity and purity of sewage effluent are also easily obtainable with General Chemical Aluminum Sulfate because of the many reasons noted below. Why not join the majority of American cities that prefer General Chemical Alum—and specify "General" for your requirements?

★ FOR WATER WORKS

1. Produces crystal-clear water.
2. Gives better floc formation resulting in longer filter runs.
3. It is a low-cost coagulant.
4. Has no chlorine demand, conserving chlorine exclusively for disinfection.
5. Superior in tests against other coagulants.
6. High in quality, its constant uniformity can be counted upon.
7. Aids in the reduction of tastes and odors.

★ FOR SEWAGE PLANTS

1. Clean, easy to handle, dry feeds well, and economical to use.
2. Simple application, requires only low cost feeding apparatus and minimum attention.
3. Clear, colorless effluents are possible.
4. Sludge digests readily.
5. Treated digested sludge dries quickly, with a minimum of odor.
6. Chlorine consumption is cut due to lower demand of clarified sewage.

BASIC CHEMICALS

GENERAL CHEMICAL COMPANY

FOR AMERICAN INDUSTRY

"Preferred by Most American Cities"

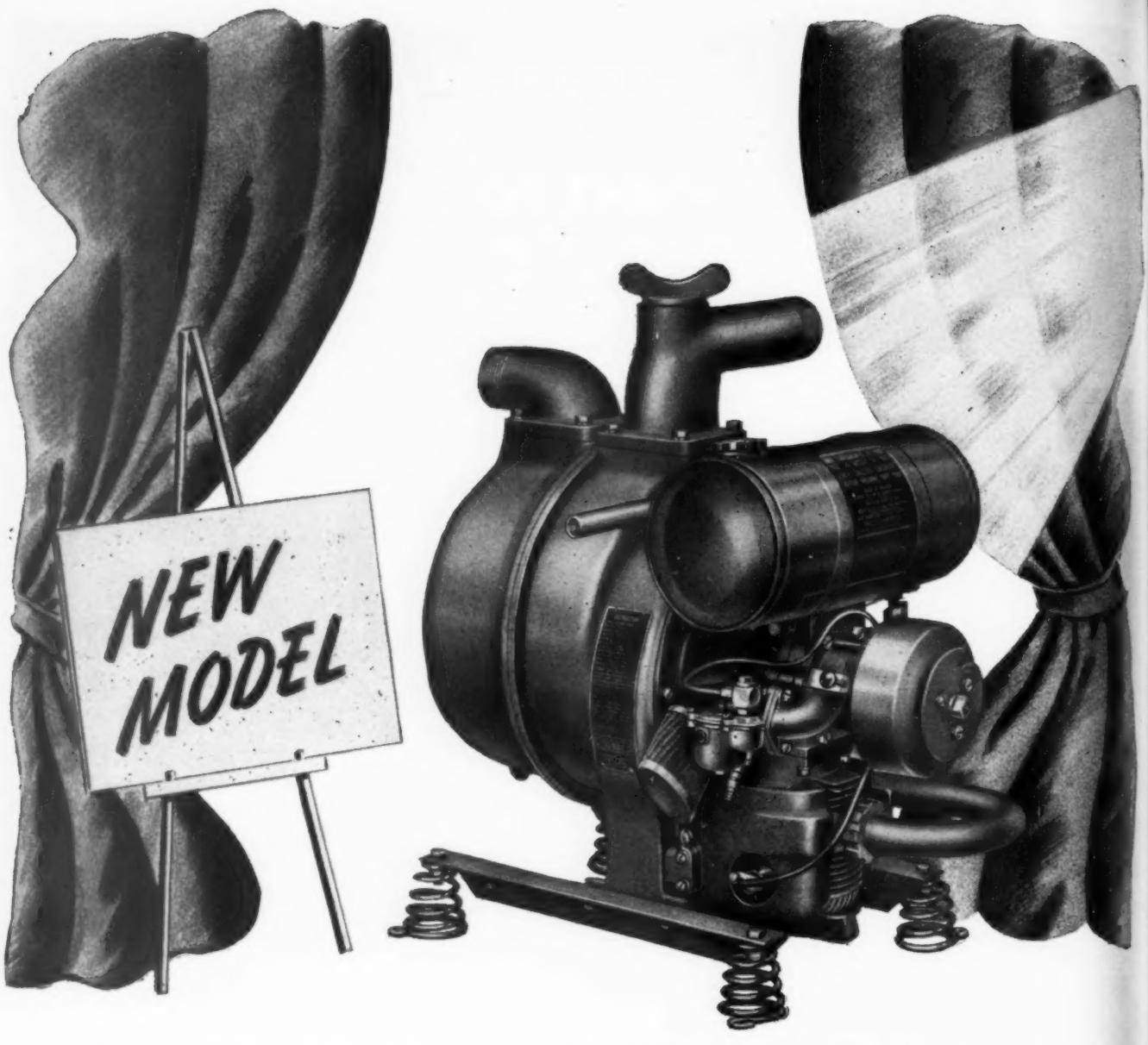
GENERAL CHEMICAL COMPANY

40 RECTOR STREET, NEW YORK 6, N. Y.

Sales and Technical Service Offices: Atlanta • Baltimore • Boston • Bridgeport (Conn.) Buffalo • Charlotte (N. C.) • Chicago • Cleveland • Denver • Detroit • Houston Kansas City • Los Angeles • Minneapolis • New York • Philadelphia • Pittsburgh Providence (R. I.) • San Francisco • Seattle • St. Louis • Utica (N. Y.) • Wenatchee & Yakima (Wash.)

In Wisconsin: General Chemical Wisconsin Corporation, Milwaukee, Wis.

In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver



NOW you can get a NEW Homelite Portable Pump

The new Model HR Homelite Self-priming Pumps are now coming off our production line.

However, only a few are being built . . . a limited quantity each month for essential civilian use. Your priority rating is your "ration coupon."

True to Homelite standards, these gasoline-engine-driven self-priming pumps are easily portable and extremely rugged. They have a large capacity . . . 28 foot suction lift . . . keep seepage at strainer level . . . and are non-clogging, foolproof and weatherproof. A new engine design gives increased power . . . with a reduction in weight.

These new Homelite Pumps can be furnished with fittings for 2″ or 3″ hose . . . and the two size fittings are interchangeable.

Write today for complete information and prices on these new Model HR Homelite Portable Pumps. Don't forget to give us your priority rating.

HOMELITE CORPORATION

PORT CHESTER, NEW YORK

***PORTABLE* PUMPS • GENERATORS • BLOWERS**

SUBMIT YOUR PROTECTIVE COATING TO THIS tough test!

It's simple . . . and convincing!

● Just coat a steel plate with the protective coating you are now using. After the coating sets, strike it heavy blows with a hammer as shown in the illustration at the left. Note what happens!

NO-OX-ID Won't Shatter

If you are using NO-OX-ID, the *original* rust preventive, you will find a condition similar to that shown in the illustration . . . the coating merely dimples when the hammer strikes it; it does not shatter or crack in the least. Metal beneath retains its protective film.

NO-OX-ID Resists Abrasion

Protective coatings *must* be elastic and pliable under a wide temperature range if their inhibitors are to be active and if the coating is to resist abrasion. NO-OX-ID has these essential characteristics and, in addition, is tough, resilient, and non-oxidizing, retaining these properties indefinitely. This assures a tenacious bond.

Use on New Installations or for Maintenance

Apply NO-OX-ID to *new* tanks, pipes, valves, steel structures, and equipment, or use it in your regular reconditioning program.

Educational Film shown to your group on request

Educational motion picture, in color, showing the simple, effective methods and equipment for applying NO-OX-ID and NO-OX-IDized wrappers, is available for showing to interested groups. Let us know the date you would like to have us show the picture in your community.

NO-OX-ID IRON + OX = RUST

REG. TRADEMARK AUG. 27, 1918

The ORIGINAL RUST PREVENTIVE

Dearborn Chemical Company
Dept. Y, 310 S. Michigan Ave., Chicago 4, Ill.
New York • Los Angeles • Toronto

% PROPORTIONEERS % SOLVE CHEMICAL FEEDING PROBLEM

How to automatically treat the town water supply was a serious problem in Middlebury, Vt. But the Middlebury Water Commissioners made a wise choice . . . they called in the Johnson-Barker-Webb Co. of Nashua, N. H., representing %Proportioneers% in Vermont and N. H. Automatic flow proportional feeding equipment by %Proportioneers% was soon installed, giving complete satisfaction and 100% protection to the town water supply. A small frost-proof cellar houses the entire chemical feeding equipment, together with the main valves and meter. Chemical solution is drawn from the reagent tank through non-corrosive plastic tubing

% PROPORTIONEERS, INC. %

WATER WORKS & SEWERAGE

PUBLICATION OFFICE
330 South Wells Street, Chicago, Ill.
E. S. Gillette, Publisher

EDITORIAL OFFICE
155 East 44th Street, New York, N. Y.
L. H. Enslow, Editor

COMING!

"Problems of a Municipal Water Works Land Owner"

Is the continuation of an article of the same title which is featured in this issue. It tells the intriguing story of a water works manager who also successfully manages 13,000 acres of lands and lakes on which Akron's Water Bureau conducts commercially profitable undertakings. In this issue he tells the story of almost a quarter century of reforestation; in the next is presented his experiences in farming and the raising of fine Hereford cattle and Merino sheep on a large scale. Also of lumbering, of production of maple syrup, of fish propagation, and the regulation of fishing, hunting, trapping and recreation of Akron's watersheds and lakes. Worthy of note are the suggestions of AWWA's vice-president, looking to land ownership and land management as an important consideration in water supply practice of the future. The author is —
W. A. LA DUE, Chief Engr. and Supt.,
Bureau of Water and Sewerage, Akron, Ohio.

"Operation of Activated Sludge Plants"

Frequently tries the soul of the operator and the plant manager. As an aid and practical guide to activated sludge plant operators, this article has been developed by a highly observant contributor of long experience in dealing with the process and studying its behavior under a variety of conditions. We are happy to be able to reproduce this highly valuable operating guide which was developed as a lecture delivered to the recent Pennsylvania Short Course for Sewage Works Operators, and written for small as well as large plant operators, by—
DR. GAIL P. EDWARDS, Chief Chemist,
Dept. of Public Works, New York City.

"Protection of Electrical Control Equipment and Idle Motors"

Is an article which describes a novel method and unit for protecting control panels, etc., and idle motors against moisture and condensation which is responsible for corrosion of control panel wiring and contact parts, or insulation failures in motors which are required to remain idle. The method and equipment is inexpensive and constitutes cheap insurance against electrical equipment depreciation and failures. It is being described at our request by—
H. VANCE CRAWFORD, Engineer,
General Electric Co., Schenectady, N. Y.

"Deep Well Water Supplies"

Is the subject of a series of articles dealing with this important phase of water supply. The first article in the series deals with the important consideration of developing the most effective specifications, taking of bids, evaluation of bids, selection of the driller, nature of the contract and requirements of the driller and developer of the well, methods of payment, etc. The author, who has had considerable experience in developing deep well supplies for municipalities and industry is—
FRANK E. HARLEY,
Consulting Engineer, Fair Lawn, N. J.

"An Improved Design for Gate Valves"

Constitutes an argument for gate valves of improved design, involving the use of non-corrodable metal inserts for the gate and the gate seat where corrosion has been responsible for poor valve operation, failure to seat properly and valve freezing when closed. Based on Baltimore experiences an improved design for gate valves is suggested and illustrated by detail drawings. The contributor is—
GORDON C. O'BRIEN, Design Engr.,
Bureau of Water Supply, Baltimore, Md.

"Design of Control Flumes for Grit Chambers"

Constitutes a simple aid for use with the Bushee method of designing velocity control elements in grit chambers as described in Water Works and Sewerage, Dec. 1941. The formulas employed in designing this simple aid have been translated into a useful set of curves and a dimension sketch developed by—
W. E. HOWLAND, Professor of C. E.,
Purdue Univ., Lafayette, Ind.

VOL. 92, NO. 6

CONTENTS

JUNE, 1945

Problems of a Municipal Water Works Land Owner..... 181
By W. R. La Due, Supt. and Chief Engineer,
Bureau of Water & Sewerage,
Akron, Ohio.

Corrosion Control in Potable Water Systems..... 187
By Major Rolf Eliassen, Chief of San. Engr. Section
Ninth Service Command Engineers,
Salt Lake City, Utah.

Main Cleaning with Compressed Air..... 192
By Roscoe R. Howard,
Supt. Municipal Utilities,
Slater, Missouri.

Trenching Practice 194
By Richard Bennett, City Engineer,
Phoenix, Arizona.

A New Development in Sludge Metering..... 198
By Chas. G. Richardson, Vice-Pres.,
Builders-Providence, Inc.,
Providence, Rhode Island.

Flow and Depth in Circular Channels or Conduits..... 200
By Paul McH. Albert, Shoecraft,
Drury & McNamee, Engrs.
Ann Arbor, Michigan.

New England Sewage Works Association's Spring Meeting... 202

Free-Flow Discharge Table for Parshall Measuring Flumes.. 206
By N. W. Nester and G. C. Hanes,
Corps of Engineers, U. S. Army.

Editorial 208

Meetings Scheduled .....Ad. Page 84

Here and There with "Doc" Symons..... 86

Manufacturers' and Equipment News.....Ad. Page 92

Literature and Catalogs Received..... 106

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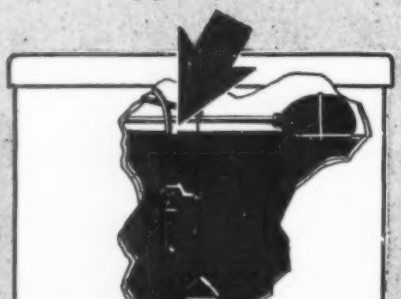
Why meters should register at 90% or more minute

The Biggest Offender



THE overflow pipe, often silent and unsuspected, has been found by experience to be one of the largest wasters of water. Running steadily, at low rates of flow, its leakage will not be registered on meters which are not maintained in good condition. If the meter will not operate on ¼ of a gallon a minute, not an unusual leakage rate, over 10,000 gallons per month will go unaccounted and uncharged for.

OF unaccounted-for water, possibly more can be attributed to under-registration of meters than to any other single cause.

This may be easily understood from the results of a survey in a city where meters were not removed from service until they became inoperative. From a typical residential street, 40 meters were removed . . . 36 of which would not even move on a flow of ¼ gallon per minute.

When you remember that 13% of all water passing through ⅝" meters is used at about ¼ gallon per minute, you can readily see the importance of having your repaired meters register at least 90% at that rate of flow.

Your Trident representative will be glad to give you the benefit of his experience in connection with modern meter shop operation.

WATER WORKS & SEWERAGE

VOL. 92, No. 6 *A Gillette Publication* JUNE, 1945

PROBLEMS OF A MUNICIPAL WATER WORKS LAND OWNER

With Particular Reference to Twenty-Three Years of Reforestation Experience

(The First of Two Articles on Land Use and Management)

By W. R. LA DUE

Supt. and Chief Engineer
BUREAU OF WATER AND SEWERAGE
AKRON, OHIO

SEVERAL hundreds of thousands of years ago the State of Ohio, together with other North Central States, was overrun by the enormous ice sheets of the Ice or Glacial Era of the Pleistocene Period of the Cenozoil Age of geological time. Alternating from one ice age to the next, with the advancing and retreating of the ice sheets, nature carried out an incredible "face-lifting" performance on the pre-glacial landscape. It was as though an enormous "bull-dozer" had leveled the hilltops into the valleys. When the vagaries of changing climate had melted the last glacier, that portion of northeastern Ohio, which later became Summit, Portage, Cuyahoga and Geauga Counties, emerged with a topography somewhat modern in appearance, except that it was a barren wilderness with nothing living to protect it from the erosions of wind, rain, snow and the changing of the seasons. The hilltops were bare and the valleys were filled with glacial flour, sand, gravel, clay, boulders and just plain mud. Coal-bearing measures, conglomerate, shales and sandstones were exposed on the hillsides and on the valley slopes.

The Author*

*Vice-Pres. American Water Works Association.

Nature's Conservation Program

"Mother Nature" had to create a soil which would sustain plant life, and in this development a gigantic natural conservation program resulted. How this was done is a matter of theory, but it was done. Perhaps the first trees of wide dispersion were conifers—the pines, the tamaracks, and the hemlocks. The Mound Builder and the Indian in pre-historic time found a wonderful country covered with forests of oak, walnut, chestnut, maple, beech and white pine; meadows of heavy grass; rivers of clear, sparkling waters. Game was plentiful—deer, bear, buffalo, wild turkey, elk and the predators. Fish filled the streams and the lakes—sturgeon, pike, muskellonge, bass and white fish. Truly it was the Indian's "Happy Hunting Ground".

Into this area at the close of the 18th and the beginning of the 19th centuries moved thousands of the soldiers of the Revolutionary War, since northeastern Ohio was a part of the Connecticut Reserve. The pioneer lived off the land. The forest gave him timbers for his home and game for his larder. The soil gave him grain and his crops. The rivers and lakes gave him fish for food, water to drink and a means of transportation. Rapidly the white man took over.

Akron's Water Supply

In 1825, in the County of Summit, the City of Akron was incorporated. In seventy-five years it found itself a center of the cereal and reaper industries and by 1910 it had attained a population of 69,000 and became, at the beginning of the automobile age, the founder of an allied industry—the new rubber industry. Water was a problem, not particularly for industry, but because of domestic shortcomings. Small fish and "pollywogs" had been discovered in the drinking water; not once, but on numerous occasions throughout the city. The private holding company, either through lack of funds, or desire, or both, failed to develop a satisfactory source of supply to meet ever increasing demands. Something had to be done about it by the City administration so the growing city in April, 1912, purchased the water company's holdings and embarked upon the water supply business as sole owner and operator.

The glaciers upon receding, had left the Akron area "on the fence" so to speak, for actually Akron sits astride the Continental Divide, with its water flowing away from it—south to the Ohio, Mississippi, and the Gulf of Mexico—north to the Great Lakes, the St. Lawrence and the Atlantic Ocean. Local adjacent watersheds are small; volume of water is not large. But the glaciers had played favorable tricks also. The pre-glacial river valleys had

been filled with some good aquifers,—sand and gravel,—which private industry had tapped with wells for industrial supply. A child of the last glacier was the Cuyahoga River, which rises in northeastern Ohio, fifteen miles from Lake Erie, twenty-five miles east of Cleveland, flows southerly fifty miles to Akron, thence thirty miles northerly to enter Lake Erie at Cleveland. The engineers retained by the city to study the water supply recommended the development of the Cuyahoga River at a suitable location fifteen miles northeast of Akron, above which point the river had accumulated a watershed of 206 square miles. Against odds engineering wisdom and foresight prevailed, and in August, 1915 the first water of the Cuyahoga was treated and pumped to Akron.

The Orchards of Akron

By this development the Akron Water Works embarked upon a career of land ownership which is the basis of the present story. Lake Rockwell, the City's impounding reservoir, consists of 750 acres of water surface and about 1750 acres of protective surrounding shore area. The latter had been farming land consisting of fairly well balanced tillable soil, grazing areas and woods. Forest areas of course had been long-since divested of marketable timber so that with few exceptions, there remained only second growth, third growth and even "slashings". For several years the new supply organization exerted most of its effort to supplying more and more water for the rapidly growing city, which by 1920 had acquired a population of 206,000. In the reservoir development the shoreline had been cleared to an elevation ten feet above flow line. Real planned development of the excess area began about 1922 when protective measures required the purchase of an adjacent fruit farm covering about fifty acres. This farm was a going concern, in good condition, well equipped and well laid out with popular fruit varieties. To protect the investment the Water Department was obliged to remain in the fruit business and more or less reluctantly decided to hire a managerial horticulturist. Other adjacent former crop areas were subsequently planted in fruit trees so that today there are 150 acres in fruit—apples, pears, cherries—together with a vineyard of 39 acres. As high as 25,000 bushels of apples have been harvested in one year and several hundred tons of grapes. A ready market prevailed at the farm as well as in nearby cities.

As soon as practicable the Water Department removed itself from private competitive endeavor by selling all its equipment to the horticulturist and with him entering into an administration-approved long-term rental contract for the operation of the orchard, farm and vineyard areas. A rigid contract was established providing:

Method of Payment—A flat rental fee, plus varying percentages of gross receipts above a certain fixed minimum income. A firm bond was stipulated.

Operational Methods—All pruning, mulching, spraying and fertilizing were to be in keeping with best practice as promulgated, recommended or approved by the Ohio State Department of Agriculture, Division of Horticulture, which organization was to be called upon at any time for inspection. Two mowings per season were required.

Use of Cultivated Lands—Methods were prescribed for the use of plow lands to insure crop rotation, ground cover and erosion control.

Use of Buildings—Three dwellings, a large sorting and storage barn and a garage were set aside for the lessee's use.

Sanitation Control—Sewage disposal and water supply for dwellings, approach to the reservoir and trespass on shore lands were rigidly outlined.

Gratifying results were obtained under the contract which proved fair to both sides. The principal varieties of fruit include Baldwin, Stayman Winesap, Jonathan, Grimes Golden, Wealthy and McIntosh apples; Montmorency, Windsor and several varieties of sweet cherries; German prunes; Bartlett, Sheldon and Seckel pears and Concord, Moore's and Worden grapes. It appears that each locality develops a desire for certain grades and types of fruit. By experience and trial, the above-named varieties had proven acceptable and in demand for the local trade, so that the crop was disposed of readily. Not only did variety, care and attractive packaging bring results but the orchards acquired a reputation for employing successful methods. Grading by the State Division of Horticulture had shown 95% or better in numerous inspections. As a result, the farm and its operations were held up as models. Unconsciously this had the effect of raising the level of efficiency of the surrounding farms.

Recent war years have brought the problems attendant to labor scarcity, which will eventually correct itself. We expect to continue operations under these or similar lines until such time as the orchards prove to be too old to be profitable. At present the policy is not to replace any trees removed but rather to provide ground covering by grass or reforestation as hereinafter described.

Reforestation

Over and above the problem of use of orchard areas, there remained some 1600 acres of shore lands to be considered. These had been originally farms of varying degrees of diversity and usefulness. In considering the treatment of these areas, the requirements of water supply were paramount. It was realized that around and above any reservoir, the conditions of the soil, cultivation, geologic formations, grazing and forest cover, all contribute to the quality of the water reaching the reservoir. In our case, restoration of forest cover seemed to offer the answer.

The native covering of tree growth, found upon any landscape defines, in the broad sense, forestation. Reforestation is the restoration, by man or nature of that which man or other causes has removed. In all forested areas a certain amount of water content is removed from the soil by transpiration through plant life and trees. This may appear as a debit but any depleting effect is offset many times by the prevention of soil erosion with resultant silting of reservoirs; flood reduction through retardation; the development of soils and the actual ground storage of waters. Shore protection appeared essential and forest cover presented a source of real control of human activities and an effective means of sanitary protection.

Full Use of Native Flora

A physical survey of the area disclosed eroded areas, "slashings", native forest, scrub cover, old plow lands, swamps and bogs. Some areas would not support tree growth so that a study of the native flora species proved valuable, especially in the light of the purpose and end point of the operation. In slightly moist areas, larch proved excellent. For erosion control locust and honeysuckle were effective and particularly hardy. As a ground builder and ground cover the quicker growing varieties of evergreens were selected. The value of a mat of pine needles in the retention of moisture and in subsequent soil building is well known. Where woods existed and for color control it appeared essential to keep deciduous tree leaves out of the water, a dense screen of evergreens was planted along the reservoir shore between the deciduous growth and the water. This accepts the theory that evergreens will catch, entrap and retain the falling leaves.

Forestry Methods

A survey of native predominant species disclosed maple, elm, walnut, chestnut (now gone), oak, dogwood, beech and tamarack. Proximity of the reservoir rather limited reforestation species to the several varieties of pines. For barren soils, including "borrow-pits", jack pines were ideal; for ornamental effects, arbor-vitae, Norway and Blue spruce proved satisfactory; for general cover, Scotch, Austrian, Corsican, red and native white pines were effective. At the request of the Forestry Division, we have experimented also with southern pine, western spruce and pitch pine, with varying results. There were of course exceptions where small areas were eventually planted with walnuts, tulip, maple and locust. We made our first planting of any consequence in the spring of 1922 using mixed pines.

Signs of Spring—Akron's Planting Crews are Out.
(Note paired two man teams—shovel man and planter. One man has just brought up a bucket of "mudded" transplants. Close-up of mudding operations appears further on.)

It should be related that the advice and experience of the Ohio State Division of Forestry and that of the Federal Government have proven of immense value and are free for the asking. Such advice should be sought and followed.

The State of Ohio maintains several nurseries in which thousands of seedlings of many varieties are produced annually. Throughout the 23 years since 1922 these seedlings have been secured in quantities up to 200,000 per year. The price is nominal where public reforestation is the established purpose.

Methods of Planting and Transplanting

Planting agencies have used two methods for the transplanting of seedlings from nursery stock. The first involves planting direct in permanent and final location. Due to the tenderness of the two to three year old seedlings, handling in rough territory, transportation and planting in general, this method produces a high rate of mortality. In some instances, this may mean little in final results if the losses are scattered. However, a difficult terrain may still indicate the necessity for use of this method. Our experience has lead us to accept the second method, that of purchasing one, two or three year old seedlings, transplanting them in our own nurseries until they are large enough for transfer to final location. In general, water supply practice has adopted this method. Depending upon the species this may require from two to four years before final transplanting is effective and conducive to good results.

Nursery and Its Importance

The selection of the nursery site is important. It should be the best soil available, equal to that required for a good vegetable garden, well worked, drained and fertilized. Since the tree is a crop, a rich soil produces a good crop and vice versa. Fertilization and plowing in the fall produces the best soil for spring harrowing and planting. Seedlings are ordered in late summer for delivery the following spring. We are usually notified a week in advance of the date when the seedlings are ready for delivery at the State Nursery. They are removed, moistened, wrapped in bundles of 1000 in peat moss and boxed for delivery. So far as handling of pines is concerned, we have drilled our men with this one slogan: "*Never* allow the roots to dry". This principal is basic and never-to-be-questioned.

Since many thousands are handled we have adopted the practice of "heeling in" the seedlings in soft ground upon receipt at our nursery. The bundles are broken and the seedlings placed in shallow trenches in moist earth, where they are covered loosely with the peat moss and earth. If left in bundles heating will occur with resultant moulding and irreparable damage to the roots. The young trees as "heeled in" may be watered from time to time until set out in the new nursery.

The spacing of the young trees in the nursery will of course vary. Species of tree, soil character and cultivation methods will dictate. Our current practice is to place seedlings two to three inches on center in rows two feet apart. A trench about four inches deep is prepared in damp (not wet) soil and the seedlings transferred on a planting board. Several steps are involved. First a hole about two feet in diameter and one foot deep is excavated, in which a rather "sloppy" mud is prepared. Seedlings from the "heeled-in" rows are removed in bunches of 75 to 100 and their roots thoroughly smeared in the mud bath; being removed a few at a time to a table where they are placed on the planting boards immediately before planting in the nursery rows. Upon removal from the boards, the earth is pressed firmly against the roots and the parts above ground straightened. A nursery planting crew consists of five men—a "mudder" who prepares the planting boards; a "carrier" who delivers the boards to the planters and also keeps the "mudder" supplied with properly prepared seedlings; two "planters", one to plant the trees and the other to fix the final set; and one "digger" who prepares the rows in advance of the "planters". Throughout the process, the slogan —"*Never* allow the roots to dry"—is strictly followed. Several crews may be employed at the same time on different areas where the number of seedlings involved is large. Varieties are never mixed in the nursery, due to different growing characteristics.

Soil conditions will determine the nature of cultivation. In sandy soils, it is possible to cultivate as often as is necessary to keep down weed growth without disturbing the roots of the seedlings. In heavier soils, this is not

The Beginning of a Nursery

3-Year-Old Nursery Ready for Tapping

possible without risking damage. Light depth cultivation to kill weeds is sufficient. We have purposely selected nurseries in sandy loam. Even so we have, after experimentation, adopted the policy of no cultivation, allowing the young trees and weeds to grow together naturally. Trial patches using both strict cultivation and no cultivation have indicated better results from no cultivation. In Ohio we have learned that weed growth can be of immense value in protecting the young trees from the direct rays of the hot summer sun.

Final Transplanting

In final plantings, selection of species depends upon the soil conditions and characteristics at the site. An attempt is always made to determine and use the best species available, as hereinbefore mentioned. We experimented with both fall and spring planting. Here again, the advice of State and Federal authorities proved valuable. Type of soil, species of tree and climate were of prime consideration. For our purpose, we have adopted spring planting as standard. It fits in better with the more advantageous use of our labor personnel; in spring the ground is more moist and more easily worked; there is little danger of roots drying out; it coordinates more closely with nursery practice, and it obviates danger of loss through frost upheaval.

Seedlings are left in our nursery for two or three years and, for certain varieties as long as four years. Rate of growth dictates. Red and Scotch pines grow the faster; spruce, southern and white pines the slower. It has been our experience with older transplants, that the roots become interlaced and entangled, so that removal is difficult without damage. Older trees are not so liable to survive disturbance. Two years also proved the best transplant age for several varieties of deciduous trees such as oak, maple, walnut and tulip. Locust root sprouts are transferred any time. Best results were obtained from planting "stratified" walnuts direct as seed. Several hundred hybrid chestnuts were transplanted direct from commercial nursery stock. These were carefully protected by rabbit guards and have thrived acceptably. Rabbits and mice also proved a nuisance among seedlings in our nursery and necessitated the use of poisons.

In the transplanting of evergreens, several steps are involved, quite similar to the initial handling of seedlings as above described. The transplants are removed by carefully loosening the earth and then immediately submerging the young tree roots in the "mudhole". If the planting area is considerable distance from the nursery, lethal drying of the roots may result unless they are well protected by placing in containers and the roots well covered with moist earth. For this purpose we use wooden boxes, 20 by 20 by 16 inches deep, affording sufficient space for 400 to 800 trees, depending upon age and variety.

At the distant site, transportation and planting difficulties may necessitate "heeling in" and caring for as previously described. In any event, as close to planting time as possible, the roots of the transplants should receive protection against drying by the "mudhole" treatment. "Mudded" trees are transported in buckets to the planters where one man prepares the hole while the other plants. A crew is usually four men—one "mudder"; one "carrier" and two "planters". The holes will vary with the species, some having longer or wider root growth. In general, the hole should provide well loosened soil to surround the roots without crushing. Well-organized crews, in our experience, in fairly open areas, can av-

Boxes of Transplants from Nursery, Ready for "Mudding" and Planting

Some Seven-year-old Scotch Pine on Mogadore Watershed

erage 400 to 600 trees per man per eight-hour day.

Tree Spacing

Spacing of trees depends upon the results desired and upon the species involved. Here forestry methods, advised by State and Federal agencies should be followed. For quick cover and complete eradication of competitive ground cover, plantings as close as 6 by 6 feet (1200 per acre) may be used. If timber is ultimately desired, such close planting, with subsequent trimming, after many years, will prevent the development of low branches. Long, straight trunks with best saw timber value will result. At our Lake Rockwell plantings, we started out with spacings 6 by 6 feet, later increasing this to 7 by 7 feet and now we are of the opinion that 8 by 8 or 8½ by 8½ (680 to 600 per acre) is ideal for plantings around reservoirs for general all-over usefulness.

Hazards and Preparedness

Forest fires are a potential menace to reforestation. To guard against this hazard constant patrolling by the general reservoir patrolmen is required. Each of our patrolmen carries with him at all times in his car two five-gallon capacity filled portable water containers, with hand-operated pump and spray nozzle. In the past twenty years, these have proved their worth many time in subduing fires through early contact. Fire lanes of generous width (over 100 ft.) are provided between plantings in open areas. These lanes are bush-free and are mowed at least twice per year where topography will allow. Where plantings are adjacent to traveled roads, fire lanes are kept free from weed growth by frequent plowings during the year. Lookout towers are a necessity for adequate patrol. Access roads have been built entirely around our reservoir, not too far back from the water's edge, to permit easy access. Branch roads lead to the more remote areas. In constructing these roads, cinders from our power plant provide excellent road material for an all-year-around surface. Because such roads afford vistas of exceptional beauty, it is to be regretted that the public cannot be given access. Such practice, however, is neither conducive of safety from fire hazards, nor of satisfactory sanitary control. Reservoir patrol can definitely become a vital part in successful forest fire patrol.

A "Mud-hole"

(An important operation is the "mudding" of transplants promptly after lifting from nursery and preparatory to hauling to the planting site.)

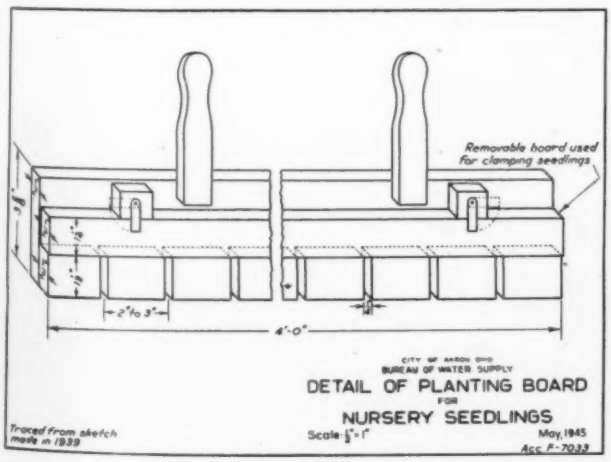
Next to forest fires, blight is the greatest potential hazard to forestation. No absolute protection is possible; we can only strive for control. The stunting of growth, the reduction in the desirability of the ultimate product and the actual killing of the tree are but three results of tree disease. We have witnessed some tragic examples of tree blight in the passing of the chestnut and in the ravages of elm disease and the white pine blister rust. We have, however, had gratifying results with the Chinese hybrid species of chestnut, which have somehow acquired immunization. We are not attempting to propagate elms but the hardy "swamp" elm has as yet been little affected by blight. To control and protect our white pines from rust we have enjoyed the close cooperation of the State Forestry Division in eradication of currants and gooseberries (Ribes) which appear as important members of the "host" cycle. Fortunately, to date, our white pine stands have thrived very well indeed.

Fungus diseases may be controlled by fungicides and care in pruning. Careless logging, or cutting and felling of trees against remaining growth, often produces wounds which leave the tree at the mercy of decay. "Slashed" or carelessly logged areas are open invitations to fire, insect and disease.

In well-established stands, animals cause little permanent damage. A natural balance is ultimately established between small game such as rabbits and groundhogs and the predatory fox. Bird life abounds. Wild duck and geese use our lake as a part of re-established migratory lane and its waters to rear their young. In fact we have one pair of eagles that have nested for years near a small swamp area. Deer are appearing in increasing numbers due to forest cover and protection.

Lake Rockwell Plantings

Using the methods outlined above, we have set out over 600,000 trees at Lake Rockwell in the period beginning in 1922 and including the spring of 1945. True, we have used a preponderance of pines of the several varieties but we have also made creditable plantings of oak, tulip, walnut and maple. When bank wash and erosion proved unsightly, willows were planted with quick satisfactory results. Where there remained fairly satisfactory natural cover our activities have been given to clearing and replacement in kind. In general, we have described acreage planting. For ornamental landscaping we have of course resorted to "spot" plantings, particularly along the shore line, on promontories, high points and bays. Arbor vitae, Norway and



Detail of Planting Board

(So useful for planting seedlings in the nursery.)

The Planting Board in Use

Showing how the board serves to get the seedlings uniformly spaced and at proper depth.

blue spruce, dogwood and wild crab have proven very effective and afford a pleasing appearance. We believe that increased air travel of the future will appreciate bulk landscaping, planted with the sky-view in mind. We maintain a nursery to facilitate "fill in" planting and for transfer to lands on our other reservoir areas. In the interest of variety and a continuing eventual timber crop, we have "skip" planted areas anticipating eventual fill-in. To our satisfaction, natural seeding has taken place from some of the older plantings. In mowing, these seedlings are guarded carefully.

Equipment

One of the really interesting things about forestation is the small amount of equipment involved. Outside of the plow and harrow to prepare nurseries, the only tools needed are spades, shovels, buckets, boxes, seedling tables, planting boards and a small pick-up truck. The hauling of water may be necessary in the more remote areas. This would require water barrels or drums. All these are found in any water works. Surely no operation of so great importance can be carried out with so little investment for equipment. Even the seedlings at the State Nursery costing $1.00 to $4.00 per thousand (averaging $2.50), would amount to only $2500 per million—enough trees, counting fire lanes and roads to cover over 2,000 acres, equivalent to a little better than one dollar per acre.

Personnel

As mentioned, we in Ohio prefer spring planting, which can be started in March, as soon as the ground has passed from the muddy stage, and can be carried through until late May. In backward seasons, we have planted in June with good results. Ordinarily, for labor crews this type of work becomes an acceptable interlude between winter activities and the start of spring and summer construction. It is seldom that important work interferes and, of course, such work should not suffer. The men like such a change and look forward to it. We have employees who have participated in tree planting each year for over 20 years. During depression years such work offered a maximum of man-hours with a minimum of expense for equipment and material. Fortunately for WPA activities, we had a backlog of thousands of seedlings in our nurseries during this period and transferred thousands of transplants to our reservoir lands. It proved to be good, healthy, profitable work with far-seeing results. We intend to maintain sizable nurseries for postwar, "just in case". In any event, there is no postwar program which offers more in the development of a natural resource or has a greater nation-wide appeal.

Costs

Again we believe forestation offers much in the way of very worth while development at low cost. For acreage plantings, assuming seedlings at $2.50 per thousand and average common labor at 75c per hour (50c to 90c) we have the following average unit costs:

Costs per 1,000 Seedlings

Seedlings	$ 2.50
Transportation from state nursery	1.00
Transplanting in nursery	6.00
Care in nursery	0.50
Planting in final location	15.00
Equipment and truck	1.50
Supervision	3.00
*Losses, conting., etc. (20% approx.)	5.50
Total cost per 1,000	$35.00

Mixed Pines Seventeen Years Old

*It is of interest to record here that our losses have not been 10% in transferring from our nursery to final location.

Other Reservoirs

Prior to 1929 about 500 acres of land had been purchased in the upper valley of the Cuyahoga River 50 miles northeast from Akron, in an area known as East Branch. During the depression years, this area was projected into a reservoir area by the purchase of an additional 1,000 acres. Under a PWA contract about 600 acres were cleared, a public road raised and a rolled-earth dam and spillway constructed. By 1939 this created a lake, having a water surface of 450 acres and a shore area of 1,050 acres, to augment domestic supply. Provision for reforestation was started at once by the creation of a small nursery maintained at about 20,000 seedlings. From 5,000 to 10,000 transplants per year have been set out in shore areas. This spring (1945) the nursery has been augumented by 38,000 seedlings.

Watch for Mr. La Due's second article in our July issue, telling of profitable commercial uses of "Akron's Acres."

In the depression year 1935-36 when it was indicated that work relief was necessary, the Water Department purchased about 2,750 acres of land about 8 miles east of Akron in the valley of the Little Cuyahoga River. By the clearing of about 1,200 acres, the reconstruction of a public highway and the building of an earthen dike and rolled earth dam, a lake of 1,000 acres was created as an industrial water supply, known as the Mogadore Reservoir. This work was done almost entirely by WPA labor and methods, thus affording work relief to as many as 2,000 men at one peak time. This reservoir was filled by early 1939. Excellent opportunities for reforestation activities (as described hereinbefore) were presented and accepted. A nursery of over 150,000 seedlings was established during the first year of construction—1937. Two years later, transplants were available for handling by relief labor. In the interim (1937-1939) transplants were secured to the extent of some 50,000 from Lake Rockwell nurseries. This use of a nursery, well-stocked by previous planning, affords a preview of what can be done postwar in reforestation planning.

Postwar

Now is the time to establish nurseries if we are to receive maximum results in a field of public endeavor which bids well to receive nation-wide enthusiastic reception. The following excerpt is made from an editorial appearing in the *Cleveland Plain Dealer* issue of March 19, 1945:

"The Legion Joins Up"

"The conservation movement in Ohio gains a powerful and welcomed ally with the inauguration of a reforestation program by the Ohio department of the American Legion.

"The decision of this veterans' organization to join the battle for the restoration of the state's most vital natural resources—soil, water and trees—was made quietly some months ago.

The Legion reveals to the uninitiated reader the extent to which conservation can be made to pay almost immediate as well as long-range dividends to the people of Ohio—and to all the people whether urban or rural residents.

"Fully aware that conservation calls for numerous measures, both public and private in nature, the Ohio American Legion has decided to place its emphasis on reforestation.

"We hope its action will inspire many other influential organizations to join actively in this movement which has as its purpose the preservation and restoration of the great natural resources which have been the physical foundation of the American way of life."

In 1922, the public evinced very little interest in "tree-planting". Reforestation programs received meager support and, in some instances, actual opposition arose. Today reforestation has become one of the most popular of conservation efforts. It must be more than an effort; it is a national necessity, *Now and Postwar.*

CORROSION CONTROL IN POTABLE WATER SYSTEMS

A Discussion and Conclusions Reached as the Result of Recent Observations, Studies and Field Experiences at Army Posts

By
MAJOR ROLF ELIASSEN*
Chief of San. Engr. Section,
Ninth Service Command Engineers
SALT LAKE CITY, UTAH

WATERWORKS engineers are faced with an extensive program of corrosion control in an effort to conserve the huge investment in ferrous metals encountered in water distribution systems and the services of consumers. The great quantities of water used, together with the demand for a low unit cost of water, have led to the search for an effective and economical means of corrosion control.

The Author

Research in the field of corrosion of metals has disclosed many of the basic factors which govern the electro-chemical phenomena involved. These researches have led to certain methods of control, many of which are applicable to industrial process waters where cost of prevention and potability are not governing factors. These methods include the use of corrosion resistant metals and alloys involving the elements of copper, nickel, silver, chromium, zinc, and others. Extensive use is also made of the lining of metal surfaces with glass, cement, enamel, plastics, rubber, and other organic materials. The addition of chemicals such as chromates to the water to induce passivity of the metal surface is also used in many industrial water systems.

Effect of Temperature

Temperature plays a vital role in the corrosion of ferrous metals. This is emphasized by the great number of repeated failures in domestic water heaters and tanks. West[1] has shown that in closed systems the rate of corrosion activity is about ten times as rapid at 180° F. as at 50° F. At 210° F. it is ten times the rate at 180° F. If the hot water systems are of the open type so that oxygen and carbon dioxide gases may escape to the atmosphere as the temperature rises, the change of corrosion activity assumes different characteristics. Friend[2] has shown that in an open system, despite the decrease in oxygen concentration with temperature rise, the rate of corrosion increases to a maximum near 176° F., after which it decreases until at the boiling point the rate is practically zero. Most of the domestic water systems in use throughout this country are of the closed type, with little opportunity for the release of dissolved gases. Many systems are uncontrolled to the extent that temperatures rise almost to the point of boiling. The need for additional research on the control of corrosion at the higher temperatures ranging between 150° F. and 200° F. is a vital one.

Dissolved Oxygen Removal

One of the most effective means of preventing corrosion is to remove the dissolved oxygen. Two practical methods of oxygen removal involving deaeration are commonly practiced. One method is to heat the water to a point just below boiling and vent the released gases to the atmosphere. At this temperature the solubility of gases in the water is virtually zero at atmospheric pressure. The cost of heating and subsequent cooling would be prohibitive for large systems.

The other method is to pass the water through an evacuated chamber, either with or without heat being added to the water. Vacuum deaeration could be accomplished without much additional cost at a treatment plant and would protect distribution mains as well as the pipes and equipment of the using agencies. This method of deaeration when practiced by the individual consumer, might involve repumping of the water. Economic studies would be necessary to determine the applicability of these methods of oxygen removal.

Oxygen may also be removed by a process known as deactivation[3]. The water is passed over beds of scrap iron or steel to induce oxidation of the iron and concurrent deoxygenation of the water. Other reducing agents such as sodium sulphite can be used for deactivation. Further treatment is frequently required to remove suspended or colloidal material, thus involving additional expense which must be charged to corrosion control.

The opinions expressed in this article are those of the author and are not to be construed as representing the policy of the War Department. This statement is being made at the request of Major Eliassen.

Protective Coatings

Some of the greatest possibilities for the economical solution of the corrosion problem will be found in the provision of protective coatings on the metallic surfaces in contact with the water. Some of the inexpensive coatings have been known to deteriorate with use and cannot be renewed. When this takes place the surface of the metal is exposed to the corrosive action of the water. Zinc coating of pipes, as in the galvanizing process, is typical of the coatings in this category. Other coatings, while they may last indefinitely, may be too expensive for adoption by the water works profession. The ideal coating should be economical and either durable or easily replaceable.

Many attempts have been made to form a calcium carbonate coating on metallic surfaces. This is most frequently accomplished by raising the pH with soda ash or lime. It must be emphasized that increase of pH alone will not assure protection against corrosion in the ranges of pH met with in potable water supplies. Wilson[4] has shown that pH has little influence on the rate of corrosion between the values of 5.0 and 11.5. In this range the concentration of dissolved oxygen in the water is the principal factor influencing corrosion.

Raising the pH may induce the formation of a calcium carbonate scale provided sufficient calcium and carbonate ions are present to form a precipitate. The saturation index of Langelier[5] and the stability index of Ryznar[6] are useful in determining the necessary dosages of chemicals to permit the precipitation of calcium carbonate. The mere existence, however, of conditions which would permit scale formation does not necessarily signify that a protective scale will be formed on the pipe. The indices do not take into account the rate of scale formation. Ryznar[6] states that the "index does not indicate how much calcium carbonate will deposit; whether a state of supersaturation will be present which will be great enough to produce a precipitate;

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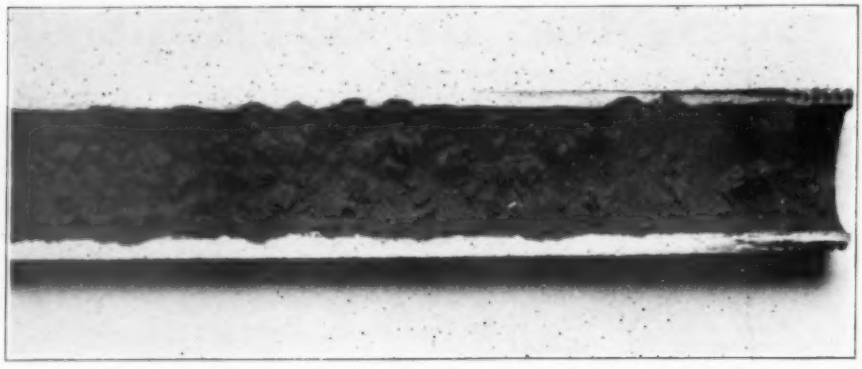


Tuberculation—Flow in Pipe Impeded, Usually Pitting Underneath

and whether it is great enough to give a protective film."

It is conceivable that the rate of formation of tuberculated surfaces composed of the products of corrosion may be greater than the rate of formation of the coating of precipitated calcium carbonate. In this case little protection will be afforded. Dangers are also inherent in the scaling of hot water heaters and other units in which the temperature of the water is raised. In their extensive studies on control of corrosion at Army posts, Kessler and his colleagues[7-8] have found that the porous nature of the calcium carbonate deposit permitted severe pitting and localized corrosion to take place under the coating. Thus, the value of this approach to corrosion control is open to question, more particularly in hot water systems than in cold water systems.

Research has been conducted by many experimenters with the goal of finding a chemical which might be added to the water in minute quantities to form a protective film over all metallic surfaces exposed to the water. The most important property of the desired chemical is that it shall have no effect on the potability of the water either from the physiological or the palatibility standpoints. The film or coating must be formed after the pipe is in place and be maintained by continuous or intermittent treatment of the water.

Sodium Silicate Films

Sodium silicate was one of the first chemicals which research disclosed would be useful in controlling corrosion in potable water systems. Speller and his associates[9] carried out extensive work on the use of this chemical. Their experiments showed that 40 ppm. of SiO_2 would reduce corrosion by 85 per cent in a period of fifteen days with Pittsburgh water at 110° F. Many others have obtained similar results. Stericker[10] attributes the success of silicates to the formation of a film on the surface of the metal by interaction with the ferrous hydroxide formed as the ferrous ion leaves the metal. Formation of the film is usually a slow process requiring about a month in many waters.

It should be understood that control does not imply complete protection. Usually it involves a high percentage of decrease in the rate of corrosion and tuberculation. Vail[9] explains that the film is a slightly permeable gel and the transfer of oxygen from water to metal does not entirely cease with the formation of the film. The coatings, however, are usually evenly distributed, dense and adherent enough to retain the ferrous hydroxide concentration at the metallic surface sufficiently high to interfere with the passage of oxygen from the water to the metal. The presence of calcium or magnesium salts in the water is believed to facilitate the formation of the coating.

Experience at Army posts[8] has shown that sodium silicate can be relied upon to achieve corrosion control with many types of corrosive waters. For the average water, sodium silicate having the composition Na_2O: 3.25 SiO_2 and a specific gravity of 40° to 42° Baume' has been found most desirable. The pH of the water after addition of sodium silicate should lie between 8.0 and 10.6, the upper limit prescribed for potable water supplies by the U. S. Public Health Service.[11] If a pH of 8.0 cannot be attained by feeding the above silicate, it would be advisable to add a more alkaline silicate such as Na_2O: $2SiO_2$ or an alkaline compound such as soda ash or caustic soda along with the silicate.

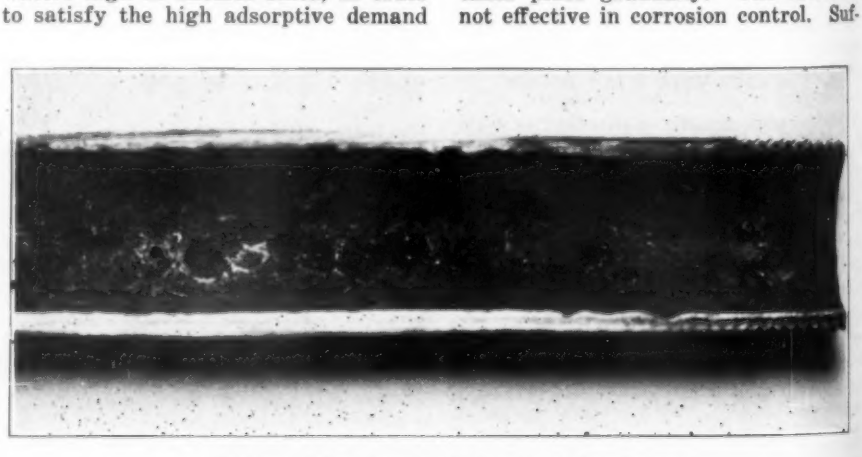
Initial dosages should be in the order of 12 to 16 ppm. (as SiO_2), except in waters high in natural silica, in order to satisfy the high adsorptive demand of the metallic surfaces. After a month, or when a film starts forming in the remote parts of the distribution system, the dosage may be reduced gradually to the point where a residual of at least 1.0 ppm. above the natural silica content of the water can be detected in the far end of the distribution system. The mere presence of residual silicate is not enough to assure the formation of a coating, but the residual is necessary for the coating to be developed and retained.

Turbulent flow characteristics should prevail in the pipes in order to assure silicates being in contact with the pipe surfaces. Field observation of the metallic surfaces is essential to determine the degree of protection obtained. When the coating has formed, the final rate of feed may be reduced to a value as low as 4 to 8 ppm., or sufficient to maintain the coating at all times. Where water is heated to high temperatures, a greater dosage may be required.

Polyphosphates as Inhibitors

Phosphates of certain types have been recognized as corrosion inhibitors during recent years. The phosphates most commonly used are the molecularly dehydrated polyphosphates known as sodium hexametaphosphate, $(NaPO_3)_6$, and sodium septaphosphate, $Na_9P_7O_{22}$. The formula for the latter may also be written as $Na_2O : (NaPO_3)_7$, showing that it is slightly more alkaline than the metaphosphate, but of similar composition. Hatch and Rice[12] claim that protection is achieved through the formation of a film on the metallic surface by adsorption of the metaphosphate from solution. Formation of the film does not take place rapidly, often taking a month to appear in the remote parts of the water system. It has been shown by Rice[13] that the results obtained will be proportional to the actual total quantity of metaphosphate passing over an area of metallic surface each day rather than the *concentration* of the chemical in the water. For this reason turbulent flow in the pipe is productive of best results.

Once the film is formed, reversion of the metaphosphate to orthophosphate takes place gradually. The latter is not effective in corrosion control. Suf-



Pitting—The Result of Localized Corrosion

ficient metaphosphate must be present in the water to replace the orthophosphate which leaves the metal. The same holds true for the septaphosphates. Control of pH has not been found necessary as the chemicals have proven effective within the range of pH found in most natural waters, from pH 5.2 to 10.6.

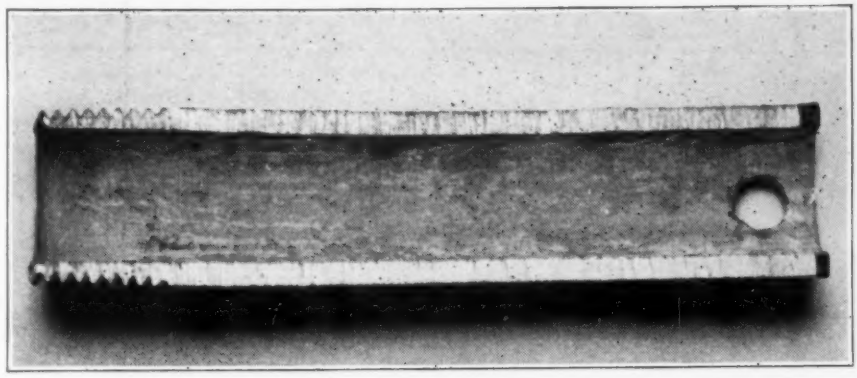
As with silicates, the control is not usually perfect to the point of complete protection from corrosion, but the reduction in the rate of corrosion may be extremely high with many waters. This is verified by the report of the AWWA Committee on Water Conditioning Methods to Inhibit Corrosion.[14] After their exhaustive survey of this subject, their conclusions were, "In ferrous metal piping systems, the use of metaphosphates will nearly always eliminate, or at least minimize, the outward manifestations of corrosion, particulary red water and tuberculation." It should be emphasized that the absence of red water alone is not the criterion of corrosion control. Chemists have shown[14] that the polyphosphates will combine with the iron in the water to form soluble complex phosphate ions and thus mask the evidence of corrosion as far as the appearance of the water is concerned. To be considered successful the chemical must form a protective coating which will minimize the loss of metal from the surface in contact with the water.

The author and his associates have utilized the polyphosphates for corrosion control at many locations on the Atlantic and Pacific coasts where corrosive waters are prevalent. With steel piping it has been found desirable to start the feeding at a rate of from 6 to 12 ppm. of the polyphosphate. The higher value is necessary where water is heated to 185° F., which is the required temperature for disinfection of tableware. Tests by Morgen and Swoope[15] show that between pH 7 and 9 a good percentage of the polyphosphates may revert to orthophosphates in 24 hours.

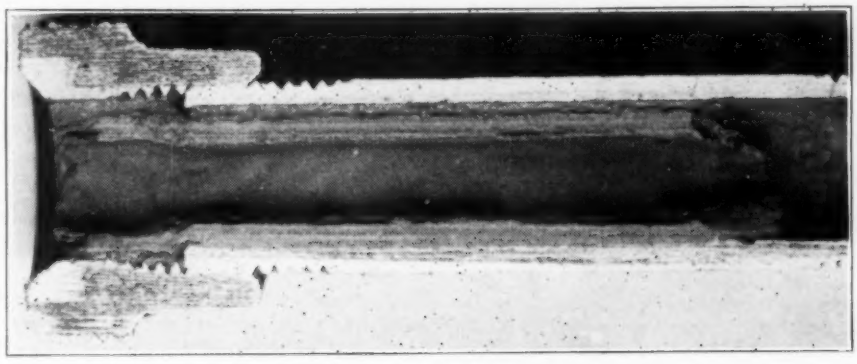
As the film develops the dosage may be cut back to the point where sufficient polyphosphate is present in the water to give a residual of at least 0.5 ppm. of the meta- or septaphosphate at the far ends of the distribution system. In some instances the final dosage to secure effective control of corrosion may be as low as 2 ppm. in lines carrying cold water. More generally a dosage between 2 and 6 ppm. is required. Where maximum protection is necessary at 185° F. the ultimate feed may be even higher. Determination of minimum dosage depends upon residual metaphosphate present and observation of actual results on the metals in contact with the water.

Combination Treatments

Polyphosphates and silicates have been added together in some cases of corrosion control where feeding each chemical separately did not give the protection desired. This combination is particularly desirable where the water has a scaling tendency which will lead to clogging of pipes when silicate is used alone. Dosages would be somewhat less than for each chemical alone and can best be determined by experiment. The author has obtained good results using 2 to 4 ppm. phosphate and 8 to 12 ppm. silicate on corrosive waters.



Protective Coating Stops Corrosive Action



Sealing—Too Much Coating—And Not the Right Kind

Tetrasodium pyrophosphate has been used successfully in the mitigation of corrosion with dosages (anhydrous basis) similar to those employed with metaphosphates. Some authors[8] have reported on the use of a mixture of pyrophosphate and an organic material derived from the fermentation of certain plant juices. Sufficient experimental data and reports of field experience are not available on the use of either pyrophosphates or organic compounds to determine the conditions under which these chemicals can be used in the control of corrosion.

Proportional Feeding and Test Loops

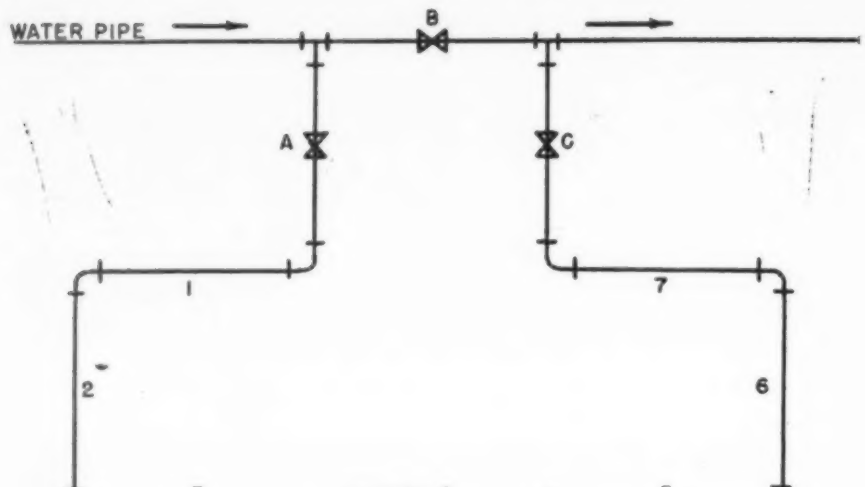
Proportional feeding of the inhibiting chemicals plays an important part in the success of corrosion control. Hypochlorinators of various types have given excellent results in feeding solutions of phosphates and silicates. These feeders may be either the simple hydraulic displacement type for low flows or the plunger and diaphragm types for higher flows. Frequent cleaning and flushing is desirable in order to prevent clogging of the apparatus. Many other types of feeders can also be utilized, but solution feed at a rate proportional to the flow is recommended for most consistent results.

Test loops provide the most accurate means of checking on the sufficiency of protection obtained in hot and cold water services. It is essential that test pipes of typical metals used by water consumers be installed at critical points served by the water utility, particularly at the ends of the system remote from the point or points of chemical feed.

The accompanying diagram shows a simple layout which permits the pipes to be subjected to the actual conditions of temperature and flow characteristics encountered near the critical point at which protection is desired. The test pipes can be taken down at any time without interfering with the supply of water. As many test pieces as desired can be installed in a loop of this type. The important factor is the periodic observation of the coating developed and the degree to which pitting and tuberculation are arrested. Determination of minimum dosage can only be made by frequent observation and analysis of these test pieces. At the present time there is no other economical method as effective as this easily comprehended scheme in guiding the water works operator in the selection of the treatment or the amount and type of chemical to be used for the control of corrosion at any point in the water system.

Summary

Research has disclosed many methods of controlling the corrosion of metallic surfaces in contact with water. The



TEST LOOP SHOWING
ARRANGEMENT OF SEVEN 12-INCH TEST PIPES

waterworks engineer is faced with the selection of a method which will be economical on a large scale application and will not affect the potability of the water. The method showing greatest promise at the present time is the feeding of minute quantities of chemicals which will form films or protective coatings on metallic surfaces and thus prevent the corrosion reactions from taking place, or retard them from proceeding to completion.

The empirical nature of the present state of the art of corrosion control does not yet permit the correlation of the chemical analysis of a corrosive water and the required dosage of inhibitors. Determination of initial dosage of chemicals must be based on the experience of others using similar waters and confronted with similar problems. On the basis of experience with many corrosive waters, the author believes that the accompanying table summarizes the average trend of chemical feeds which have given good results. Specific cases may vary appreciably from these average values. Actual control of chemical feed for any particular system must be based upon chemical tests of the water to determine the residual concentrations of the effectual chemicals at the ends of the distribution system. These residuals must be correlated with observations of results on the pipes themselves as evidenced by the examination of test pipes located at critical points in the system.

Remarkable strides have been made in this relatively new approach to the corrosion control problem. Extensive research and correlation of experimental data and field observation still remain to be accomplished before a satisfactory solution can be found for the protection of metallic surfaces in contact with water of any specific chemical makeup. Sanitary engineers should follow closely the development of new compounds for the possibility of application toward the solution of this problem. Analysis of the many different and unusual properties of the newly discovered silica-organic compounds, the silicones, may lead to one or more compounds which will give more positive control than presently obtainable with phosphates or silicates. The goal for which the waterworks profession is striving is the exact answer to the question of how much of what chemicals must be added to any specific water to assure control of corrosion in a particular water system.

CHEMICAL DOSAGE FOR CORROSION CONTROL

Chemical	Basis of Analysis	Dosage Initial ppm.	Dosage Final ppm.	Minimum Residual ppm.	Treated Water pH Min.	Treated Water pH Max.
Sodium silicate	SiO_2	12-16	4-8	1.0	8.0	10.6
Sodium hexametaphosphate	$(NaPO_3)_6$	6-12	2-6	0.5	5.2	10.6
Sodium septaphosphate	$Na_5P_7O_{22}$	6-12	2-6	0.5	5.2	10.6
Tetrasodium pyrophosphate	$Na_4P_2O_7$	6-12	2-6	0.5	5.2	10.6

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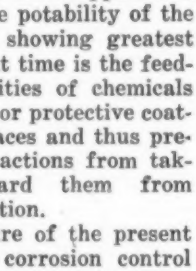
Gotaas Decorated

Col. Harold B. Gotaas, Sn. C. has been decorated by the Chilean Government with the Order of Merit.



This recognition follows closely Col. Gotaas' recent elevation to be Director of the Division of Health and Sanitation of the Institute of Inter-American Affairs.

Before joining the Army in 1942, Colonel Gotaas was Prof. of San. Engineering at the School of Public Health, Univ. of North Carolina.

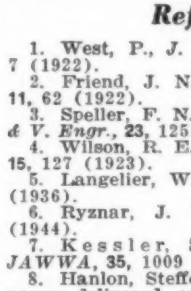
Topeka Uses Fiber Pipe for House Sewers

Upon recommendation of Wm. E. Baldry, City Engineer of Topeka, Kansas, the city commission has placed its O.K. on the use of bituminen impregnated fiber pipe for house sewer connections.

This is the product long used for electrical conduits but relatively new to the water—and sewage field. It is produced from fiber under high pressure and impregnated with protective bitumen as a binder and preserver. The joints are absolutely water tight and root-proof without the use of joint compound. The pipe is also acid and alkali proof.

Decher Made Secretary

The Essex-Union Joint Meeting, an important sewer district of New Jersey, has made Edward P. Decher, secretary, succeeding Edw. S. Rankin, well known sewerage engineer, who died March 8th.



Mr. Decher has been affiliated with the Joint Meeting since 1928 and more recently has held the position of purchasing agent and acting chief engineer for the commission. He has recently been active in the affairs of the N. J. Sewage Works Ass'n.

"Les" Jackson New Secretary of S.W. Section AWWA

Leslie A. Jackson, Manager Little Rock (Ark.) Water Works, has been elected Secretary-Treasurer of the Southwest Section American Water Works Association, succeeding George J. Rohan of Waco, Tex. A graduate of M.I.T., Mr. Jackson served in the U. S. Army until 1919. He then joined the Chicago Sanitary District; later worked for the Pitometer Company and in 1922 was engaged by American Water Works and Electric Co. In 1924 he became Asst. Supt. of the Arkansaw Water Co. of Little Rock, Ark. In 1936, when the City of Little Rock purchased this property, he became manager for the city.

Largely through Mr. Jackson's efforts was formed the Arkansas Water and Sewage Conference, which he has served in all of its offices.

In 1940 Mr. Jackson was voted the Fuller Memorial Award of A.W.W.A. in recognition of his contributions to water works management and his ability in organization and stimulation of water works organizations. He is a member of A.S.C.E. and the Association of Professional Engrs. of Arkansas. At the present time in A.W.W.A. he is Secy.-Treas. of its Finance and Accounting Division and serves on the Committee on Fire Hydrant Specifications. He is a past-chairman of the Southwest Sec. which has grown considerably as the result of his activities as Ch'm of Membership Committee.

U-1 Order Materially Liberalized

Eases Restrictions and Revokes Supplementary U-1 Orders, While Still Protecting Water Utilities with Priorities

Consistent with the policy to relax controls as rapidly as feasible under changing war conditions, the War Production Board has amended its U-1 Order effective May 12, and revoked all of the old Supplementary Orders in the U-1 Series.

Principle changes of interest to water utilities are:

1. An increase in the limiting expenditure for minor plant additions from $10,000 to $25,000 for materials and equipment.

2. Assignment of preference rating AA-1 to all classes of material (the transmission and distribution class and the meter class, only in case of actual or imminent breakdown), if it is to be used for maintenance, repair or operating supplies or for plant additions costing not more than $10,000.

3. Assignment of preference rating AA-3 to material in all classes for plant additions whose net cost is between $10,000 and $25,000, and to materials in the transmission and distribution class and meter class not required for breakdown, either actual or imminent.

4. Revised restrictions on inventory and ordering material.

5. Change in Qualitative Restrictions on Minor Plant Additions so that it is no longer necessary to restrict minor plant additions to cases where they are necessary to maintain *minimum standards*, but they can now be undertaken *if required to render service as sound and economical operating standards.*

6. Liberalization of restrictions on the sale of material.

7. Revocation of supplementary orders; the filing of Form WPB-3348 with respect to extensions to serve projects which require approval under Order L-41 is no longer required in view of the revocation of Order U-1-d.

Preference Rating Order P-141 Revised

Restrictions Relaxed on May 29th

Preference Rating Order P-141, applying to Public Sanitary Sewerage Facilities, was revised on May 29, 1945. The principal changes were to relax the restrictions of the existing order. Of most importance was the increase from $1500 to $25,000 in the net material cost of sewerage jobs, including buildings, which may be built without WPB authorization. An AA-3 rating and the allotment symbol MRO-P-141 is assigned for materials for such construction. Buildings for sewerage systems were formerly controlled by Order L-41. A revision of that order eliminates any reference to buildings so that such construction may be incorporated under P-141.

The AA-1 rating for materials and equipment for MRO purposes remains the same, but one important change relates to the exclusion from the definition of inventory, paragraph (a)(11), of materials to be used in plant additions. The restriction on the use of iron or steel pipe for house connections (par.g-1) has also been removed.

In view of the increase to $25,000 for plant additions, extensions, or betterments, Form WPB-2445, formerly required under paragraph (g)(2)(v) is no longer necessary for the types of projects described under paragraph (g)(2).

There are a few other minor changes such as the omission of paragraph (f)(3)(iii) of the report when deliveries and withdrawals exceed the base period limits due to maintenance and repair occasioned by acts of public enemy, sabotage, explosion, or by fire or flood.

George Seabury Passes

Dies Suddenly on Eve of Retirement as Executive Secretary of A.S.C.E.

George T. Seabury, Secretary of The American Society of Civil Engineers, for the past 20 years, died of a coronary thrombosis, on May 25 in New York City.

Mr. Seabury, who was 65 years old was to have retired on June 1, to be succeeded by Col. William N. Carey, Chief Engineer of the Federal Works Agency in Washington.

George T. Seabury

Mr. Seabury was born in Rhode Island, and was graduated with a degree in Civil Engineering from Massachusetts Institute of Technology. After graduation, he was engaged in construction work and served several construction companies in and about New York.

From 1906 to 1915, Mr. Seabury was an engineer for the Board of Water Supply, working on the Ashokan reservoir and dam, and later on the Kensico reservoir and dam near White Plains, N. Y. In 1915 he was appointed division engineer in charge of an $18,000,000 construction job for the water supply system of Providence, R. I. During World War I, Mr. Seabury was a major in the Army's quartermaster department supervising construction of several camps. In 1918 he founded his own construction firm and in 1923 became manager of the Providence Safety Council.

Mr. Seabury took office as secretary of ASCE on Jan. 1, 1925 and in the two decades he steered the affairs of the Society, its membership practically doubled. During his tenure the Society established a full-time office in Washington. Mr. Seabury also founded ASCE's technical journal, *Civil Engineering.*

George T. Seabury was well known to water works and sewerage men through his contacts with the Division of Sanitary Engineering in the Am. Soc. C. E. and his was a familiar face at the joint dinners of the Division and the N. Y. State Sewage Works Assoc. held during the annual January meetings of the Society.

MAIN CLEANING WITH COMPRESSED AIR

Compressed Air Also Used for Removal of Sand from Wells

By ROSCOE R. HOWARD
Superintendent
Municipal Utilities
SLATER, MO.

HERE in Slater, Mo., we have two miles of 8-in. cast-iron pipe in the main which delivers water from the two deep wells, located near the shore line of the Missouri River, and the Water Purification Plant. From the purification plant a 12-in. main seven miles long delivers the filtered water into the city.

Every year the 8-in. main between the wells and the purification plant loses some of its carrying capacity because of the annular ring consisting of silt, iron, etc., which builds up on the interior walls of the main. This deposit is about the consistency of fresh plaster on a wall and about the same thickness.

We cleaned this pipe line once by dragging a set of scrapers through it, while pumping water through.

A Trial with Compressed Air

Then we decided to try cleaning this pipe with a mixture of water and air, and it worked so well that we have cleaned it by this method once each year ever since.

The scheme is very simple. We clean a mile at a time. We remove a 4 ft. section of pipe for an outlet. We pump the greatest volume of water our well pumps will handle, which is approximately 500 gpm., and at the same time force air into the pipe from the compressor. The combined volume of air and water is thus forced through the pipe at a rather high velocity.

"Thar, She Blows!"
(A typical air-slug which really loosens up things.)

The air bubbles seem to join and accumulate to form air pockets of considerable size. Then, when the heavy slugs of water, following these light slugs of air, ram against the walls of the pipes a considerable force and scour results. Pieces of scale as much as 2 inches thick and of various widths are blown out of the pipe. For the most part, however, the material is broken up into very small pieces while traveling with such speed and turbulence.

Procedure

When we clean the two-mile main (one mile at a time) we first remove a four-ft. section of the pipe at a point where it crosses a ditch half way between the wells and the purification plant. We connect the air hose from the compressor to the pipe line near the wells. In fact, we use a piece of 1-in. copper tubing instead of a hose. We start the pumps of both wells pumping all the water through the pipe we can and start the compressor pump-

Main Cleaning by the Air-Shooting Method

(Intermittently a slug of air and little water followed by a water slug and little or no air. The author is in danger of losing a finger—see what comes out in picture on the next page.)

The Le Roi Compressor Connected to Main with 1-in. Copper Tubing

(Compressors from 80 to 210 cu. ft. min. capacity have been successfully used for the air-shooting operation.)

ing all the air through the pipe we can. After cleaning the mile of main from the wells we move the compressor to the half way point, open the main at the purification plant and clean the last half just as before.

The compressor in the accompanying picture is rated at 210 cu. ft. per min. We have at different times used one rated at 80 cu. ft. per min., one rated at 110 cu. ft. per min., and also one rated at 160 cu. ft. Each one of them did the job, but the larger they are the better and faster they do it.

With the smaller compressors we have found it better to have a large receiver on the compressor and admit the air into the pipe at about one minute intervals on 30 and off 30 seconds. With the larger compressors this intermittent operation is unnecessary.

An Easy Four Hour Job per Section

The time required with a 210 cu. ft. compressor is only about four hours on each mile. The water flows about fifteen minutes before the air starts to come through, then it starts a sort of coughing and sneezing. A lot of air will blow out, then a lot of water, rather brown and thick, carrying as much as 10 per cent of its volume of the loosened and pulverized scale of iron and silt. In about four hours the water flows clear again, and the job is finished.

As to the pictures of the scale chunks my guess is that it all started out when it broke loose as various sizes of chunks, little and big, but in its hurried journey through the pipe the most of it was crushed and ground, so that the chunks we recover are only those that broke loose within a few hundred feet of the open end of the pipe.

As for the different pictures of water and air coming from the outlet, these are pictures of the same outlet taken within about a minute of each other. It naturally works intermittently that way—a blast of air for maybe a minute and then a lot of water with not so much air in it.

Perhaps the effect of the air-water method of loosening the pipe scale can best be explained as something similar to hydraulic-mining, wherein the side of a mountain composed of rather solid materials can be torn down and sluiced away by the high velocity streams of water used. In addition, there must be a multiple water hammer effect within the main, due to the inrush of slugs of water following or tumbling through the air pockets. This would account for the jarring loose of relatively large slabs of incrustation. In any event the higher the velocity of air-water flow through the main the more effective and speedy is the cleaning.

Removal of Sand from Wells

One of our gravel wall wells leaks a fine sand. When it accumulates in the well to a height which is still several feet below the suction pipe on the pump it is sucked up into the pump causing excessive wear on impellers and bowls.

We succeeded in removing the sand once with a duplex suction pump operated by two men with a hand lever, while a third man lowered a suction pipe slowly into the sand. That job took three men three days, and wore out six sets of pump leathers.

Since that time we have cleaned out the well once each year with an air-lift. The sand, etc., is all removed in less than an hour, with no noticeable wear on anything. It takes about an hour to install the air-lift and about the same length of time to dismantle it, so the whole job is done in three hours instead of three days. The way an air-lift works is very simple. There are no valves except those in the air compressor. You do not need any jet or foot-piece for the air-lift. A string of 2-in. pipe, open on bottom and top, is lowered into the well to the bottom, and then raised to just off the bottom. Inside the 2-in. pipe a ¾-in. string of pipe carries the air from the compressor and releases it on the inside of the 2-in. riser. The air-water mixture rises up the 2-in. riser and flows out with considerable agitation and velocity. It is the high velocity which brings up the sand and also any small gravel that may be there.

As was stated, this method is a great time and labor saving scheme for clearing deep wells of sand. For the job any compressor is sufficient as long as it is not smaller than about a 5 hp. size. The amount of air that brings up the most water is the proper rate of air feed for this job.

Exhibit "A"—Specimens of Encrustation Removed

(Some pieces measured 2 inches in thickness and 3 to 4 inches in width from the 8-in. main.)

TRENCHING PRACTICE

By RICHARD BENNETT, C.E.
City Engineer
PHOENIX, ARIZ.

Part I – Earth Trenching

A TRENCH is an excavation having vertical sides and considerable depth in comparison to its width. For purposes of this article, it will be considered as being less than 6-ft. in width and not more than 30-ft. in depth, which permits excavation by modern trenching machinery.

The Author

Trenches are dug for all kinds of pipe lines, including water, sewer, gas, oil, drains, conduits, etc. The large amounts of trench excavation made necessary by the installation of pipe lines, for the various uses, has led to many improvements in this practice.

Many of the early forms of trenching machinery such as the traveling derrick, the trestle cable excavator, the tower cableway, the trestle-track excavator, etc., have all given way to the modern ladder type and wheel type trenchers.

Modern trenching machinery was first perfected about 1910. They give low cost excavation, plus fast rate of progress. They are a part of almost every pipe line construction job. Except for very small jobs, hand trenching labor is generally found inefficient and uneconomical. If the ground is free of large, heavy obstructions, and not too hard, the modern trencher is very efficient.

Parson's "Trenchliner"—250—With Offset Boom
(The boom, now operating at center, may be shifted to any desired position across entire width of chute. Thus the trencher may operate on road shoulders, in narrow alleys, close to curb lines, buildings, trees etc., without harm or difficulty. The spoil bank can be on either or both sides.)

Type of Trencher Most Suitable

The type of trencher to use will depend upon local conditions. If the trench dimensions are small, and much maneuvering is required because of restricted conditions, then some of the smaller trenchers will prove best.

Many consider the wheel type trencher is a harder digger than the ladder type. In hard and tough clays, for medium depths and widths, this type is most efficient. These designs are generally limited in maximum widths and depths of trenches excavated, the maximum being about 3½-foot width and 8½-foot depths.

Where trenches of greater width and depths are involved, the ladder type must be used. If stones, not too large, are encountered occasionally, the ladder type is more efficient to loosen them, being partly due to the vibration of the boom, whereas the steadiness of the wheel type excavator would not accomplish the same result.

On most of the ladder type trenchers, the boom may be telescoped so that the depth of the trench may be increased or decreased with little difficulty.

In any case, if the digging is difficult, then the high powered types must be used.

Some trenchers are designed for use in cramped quarters, such as narrow alleys, parkways, close to curbs, buildings or other obstructions, etc. With some the boom may be shifted to one side so that the trench may be cut close to side obstructions.

Maximum service is desired in a trencher. They are subject to hard, grueling service, and their design should sacrifice nothing which would affect durability.

With modern trenchers the spoil bank may be located on either side of the machine, or loaded into trucks or on conveyor as desired. The spoil conveyor will place the spoil bank back from the trench sufficient distance to give a good clean shoulder on which the workmen are not hindered in laying the pipe. When extensions are added to the spoil conveyor the desired height of the spoil bank may be secured to care for the earth from deep trenches.

Trenching Methods

If the trench is deeper than the trencher will excavate, there are two methods which can be used to gain extra depth, without undue expense. (a) Excavate with scrapers, sufficient depth from the surface and the full width of the trencher, so that the trencher can excavate to desired grade line. Several feet of added trench depth can be secured in this manner. The spoil con-

veyor can be lengthened so that the earth may be removed either to spoil bank or to trucks as desired. (b) Under most conditions, it is possible to remove about two feet of earth below the trencher cut, and throw the spoil back onto pipe already laid in place. Using two workmen, one with air spade and the other to shovel, this work can be done at a rather rapid rate of progress. Using the combination of these two methods, several added feet of depth can be economically secured.

Estimating Practices in Trenching

The trenching contractor is beset with many difficulties and uncertainties, therefore estimates must allow for many unpredictable contingencies. It is impossible to know exactly just what will be encountered until the trench has been excavated. The trenching estimator must judge many factors to the best of his ability.

A visual survey of many jobs will enable the estimator to determine, with reasonable accuracy, whether the job will present many interruptions; on the other hand, too much dependence must not be placed on such surveys in built-up areas. Questions concerning wells, excavations, etc., made previously in the area will reveal many facts. Many pipe line contractors have suffered great losses by not familiarizing themselves with the underground conditions to be encountered.

Much experience is required to properly estimate different conditions and proper methods of pipe line work. Some estimators estimate the job as close as existing data will permit, then add a percentage for uncertainties—a method but little better than a shrewd guess. The estimator who can accurately determine costs on two or more methods for the same job, is worthy of his hire.

In pipe line construction, the cost of trenching is usually the major item, depending upon digging conditions. The kind of earth involved makes much difference in the unit costs. These costs increase according to the types of earth somewhat as follows: light earths and sand; loam and light clays; dry, hard loams and tough clays; dense and tough adobes; coarse gravels, cemented gravels; hard caliche; and disintegrated granites. All these materials produce different unit costs.

Labor Costs

Labor costs are not materially increased with the light earths, sand loams and clays, but such costs are increased with the tough, dense clays, adobes, varying with the amount of pipe bedding required. Mud, especially if it is sticky will greatly increase costs. Unforeseen conditions, such as solid rock, boulders, water, caving soil and even quicksand conditions will greatly increase costs.

The estimate must include: excavation, sheeting, backfilling, equipment rental; moving to and from job; and if water is likely to be encountered, then an allowance must be included for water pumping and disposal.

The labor expense will include foremen; machine runners, helpers or swampers; pipe layers; laborers; timbermen; backfillers; as well as extra roustabouts. The cost of superintendence and supervision can generally be estimated as a percentage of the payroll.

Fixed Costs

Fuel, supplies, and equipment repairs will generally be a large item with most jobs. To determine the fixed costs per day, the contractor must make assumptions which are later adjusted in the light of actual facts. Some depreciate trencher equipment at 60 months total life; however, many individual pieces of equipment have lasted both much longer and even shorter time than this. Some authorities estimate yearly costs of this equipment somewhat as follows: depreciation 20%; repairs 18%; interest, insurance, and taxes 7%; miscellaneous 4%. Total fixed charges per year—approximately 50% of original cost of trencher. The total fixed costs per year divided by the units of work performed gives the actual job cost for using that particular machine.

About 4% of the payroll should be charged for small tools. Miscellaneous materials required for the work as the job progresses will generally average about 1% of the payroll. Small jobs, unless the management is excellent, will produce high unit costs.

Daily Cost Analysis Important

The cost analysis of trenching for every job should show the width and depth of trench; type of soil; the total footage excavated; the number of cubic yards excavated; the total overhead and operating expense of the trencher; the daily expense of trenching; the footage expense of trenching; and the cubic yard expense of trenching.

The unit costs should separate excavation; pipe laying; back-filling; cleaning up, moving to and from job; and overhead. The analysis should show minimum, average, and maximum day's work and reasons, together with average of all items for the entire job. These data, kept up daily, will show and determine all leaks and losses on the job.

Cleveland Trencher

(Cutting through a soft-rock formation in Texas called the Austin Chalk. Note the clean cut made. Trenchers of the ladder type are also good in shale, consolidated gravel and all but hard solid rock.)

Part II – Rock Trenching

What was said in Part I on trench excavation in dirt, may also be almost wholly applied to trenching in rock. Rock trenching is a time and labor consuming proposition. The fact that it is not often encountered probably accounts for the great variation of methods adopted on different jobs. The technical literature contains almost nothing on this subject. Ask the manufacturer's blasting experts and they merely say, "I will get you something on that." Period!

System Lacking in Rock Trenching

Most rock trenching jobs have little or no system. Costs are high; progress is slow; and those in charge make little or no endeavor to find the most economical method for that job.

In rock trenching the quality and quantity of the rock will generally determine the proper method of excavation. For economical work it is necessary to give much thought and attention to the job methods.

The types of rock encountered may vary from hardpan to dense, tough granites; each will require a different method of drilling and shooting.

There does not seem to be any current standard practice in the spacing of drill holes. Each foreman seems to have his own pet ideas—very few of which would stand much investigation from an efficiency viewpoint.

Proper spacing of drill holes will depend on the nature of the rock and local conditions, but cut and try methods must be utilized to ascertain the most economical method.

Drilling Requirements

The number of feet of hole to be drilled per cubic yard of rock to be excavated will vary greatly with different jobs, conditions, and job methods. Spacing will depend upon nature of the rock and width of trench. Properly determining this factor requires much ability on the part of the job manager. This determines ultimate unit costs.

For average rock the following table may be used to determine trial hole spacing:

Width of trench (feet)	Number of rows of holes
3	2
6	3
9	4
12	5
15	6

The outside row of holes should be in line with the trench wall. It is seldom that cross-trench hole spacing greater than 3-ft. can be successfully used. At times the longitudinal spacing can be increased to 4-ft. or even slightly more, especially in the wider and deep trenches. The greatest economy is secured in using maximum depth for holes.

The necessity for protecting adjacent structures, whether underground utilities or nearby buildings, will influence drill hole spacing.

If power excavation equipment is to be used, it is seldom possible to blast a single line of holes down the center of the trench. With but one line of holes too much projecting rock remains to be loosened by prying and barring by hand methods—thus greatly increasing costs.

Care must be taken to keep the drill holes clean until they are loaded. If the hole contains debris or water, this is best removed with compressed air. Ice frozen holes may be cleaned out with steam; this also warms the hole sufficiently so that the explosive will not freeze. A wooden plug should be driven into each hole as soon as the drilling is completed, to keep out extraneous materials; this plug also aids in finding the hole later.

Proper Quantity of Explosives

Determining the proper amount of explosive to use will require trial and error determination. Experience and good judgment helps very much. In any case carefully kept notes and records are of immense value.

In trench blasting only one narrow face is open, therefore more explosive is required than for open surface blasting. The amount and strength of dynamite to properly use will depend upon all the factors mentioned for spacing of drill holes. The amount of explosive required per cubic yard of rock removed will depend upon the nature and type of rock and the method adopted. The amount of explosive per hole may be limited by the necessity for controlling flying rock; excessive noise or vibrations; and danger to nearby underground utilities or adjacent structures of any nature.

Buckeye Model 120 Trencher
(Buckeye also makes a wheel-type trencher satisfactory for water-line trenching, requiring less depth and permissive of faster travel where the going is easy.)

Dynamite is generally used for trench blasting; the grade used depending upon the type and quality of rock encountered. The quantity required may range from about ¾-lb. per cubic yard in soft sandstone to 3-lbs. or more in the hard dense rocks.

Different rocks and formations do not blast alike to meet given conditions. The specifications for the work may limit the amount and kind of blasting that may be done on the job. Oftentimes blasting is restricted due to local conditions.

Selection of Proper Explosives

The type of explosive to use will depend upon the type and quality of the rock; local conditions; etc. The greatest waste in explosives, is in using a grade or type not suited to the job at hand. A low grade of explosive should be used for soft, weathered rock; to use high grade explosive here, is to waste much of the explosive energy. High power explosives lack propelling power when used in blasting soft rocks.

Too many use only one type and grade of explosive—generally 40 per cent strength. This is poor economy. Some arbitrarily use 60 per cent to secure sufficient shattering and also to loosen rock bound in place. If the rock is not shattered sufficiently, then a higher grade should be used. If the rock is shattered too much, then a lower grade should be adopted for the job.

A high power explosive should be used for hard, firm rock. If the bottom of the hole does not shoot properly,

A Well Braced Trench

then it may be best to use a high grade explosive at this point. In such cases place the firing charge at the top of explosives so that the explosive gases will tend to concentrate at the bottom of the hole, thus producing greater rupture at that point.

Sufficient shattering must be secured to permit easy removal of the rock from the trench. It is not possible to use ladder type of trenchers for rock trenching, except in the very soft formations. A pull shovel or trench-hoe may often be used to good advantage in rock trenching.

Rock Excavating Equipment

In shallow trenches the rock may be removed by hand. For hand excavation the rock must be broken into small pieces either by blasting or subsequent breakage.

For deep rock trenches the use of drag line or pull-shovel is most economical. These types of equipment are well suited for this work. The rock must be thoroughly broken up, and the walls sufficiently straight not to hang up the shovel. Rocks too large to be removed by the bucket, should be hoisted from the trench with chains.

Limestone is easily drilled. It is occasionally found in horizontal layers, and may be blasted like building stone. In seamy formations, the holes must be closely spaced to retain the force of the explosion. Seamy rocks permit the explosive gases to escape and the full effect is not retained in shattering. Seamy rocks, lying at an angle cause the drills to stick and bind in the hole. Relatively smooth and straight walls may be secured in blasting soft sedimentary rocks.

Granite and igneous rocks break out in rough, irregular walls. If the holes are thoroughly and tightly tamped, then the explosive will give most effective results, due to confining the explosive gases. Trap and quartzite are generally difficult to drill.

Two factors should be kept in mind at all times in rock trench excavation; the number of feet of hole drilled per cubic yard of neat excavation; and, the amount and strength of dynamite used per cubic yard of excavation; both of which sum up to: cost of breaking up the rock for satisfactory removal.

Koehring's Trench-Hoe
(A rugged piece of equipment, useful where the going is tough—boulders, hard shale, blasted rock, etc.)

A NEW DEVELOPMENT IN SLUDGE METERING

Proves the Solution of a Major Problem

By CHAS. G. RICHARDSON
Vice-President
Builders-Providence, Inc.
PROVIDENCE, R. I.

CHARLES R. VELZY, C. E. of Greeley & Hansen, Engineers, New York City and Chicago, in an important article "Problems in Handling Sewage Sludge" in the January issue of *Water Works and Sewerage*, devotes a section to "Metering." Briefly, his conclusions are: (a) The Venturi tube is the most satisfactory sludge metering unit, even though "accuracy cannot be expected"; (b) the annular piezometric rings easily become plugged with solids and one or two openings direct to the interior of the tube are more satisfactory; (c) special cleaning and flushing devices are helpful; (d) even though not very accurate, a meter on sludge is worth while since it gives at least some measure of the flow rate, indicates any sharp drop in the rate due to line clogging or valve obstruction; also informs the operator when he starts a pump, whether sludge is actually discharged and, if not, the importance of immediate investigation of pump valves or other possible sources of trouble. Mr. Velzy remarks further that the handling of sludge is always troublesome and that meters, like other units, must have routine attention by daily flushing of connections and frequent cleaning of the meter itself.

The Author

The writer subscribes to many of Mr. Velzy's comments; but, at the same time it should be said that numerous Venturi meters, where properly installed, are measuring sludge flows accurately. The majority of these are on activated sludge and generally employ the familiar "water column operation," i. e., two vertical pipes ten or twelve inches in diameter, one connected directly with the inlet and the other with the throat of the Venturi tube, and each containing a float which is cable-connected to a differential gear mechanism in the registering instrument. A small stream of clear water is continually introduced at the top of each pipe, creating a backflow into the Venturi tube and maintaining all connections free from deposits.

A Recent Development in Sludge Metering

As Mr. Velzy points out, it is the handling and measurement of primary sludge which presents the most serious difficulties. This also can be successfully accomplished with proper flushing; it requires, however, a much different type of installation. The continuous injection of a stream of water into the Venturi tube and its connections is not new, but in a recent development "something has been added" which makes certain that under no condition can sludge creep into the small piping or the metering units. At the same time inaccuracies, caused by inflowing water modifying the two pressures from the inlet and throat of the Venturi tube, are averted. Several installations of this type by the writer's company, have been trouble-free and accurate in performance for many months. Settling tanks between Venturi tube and the indicating and re-

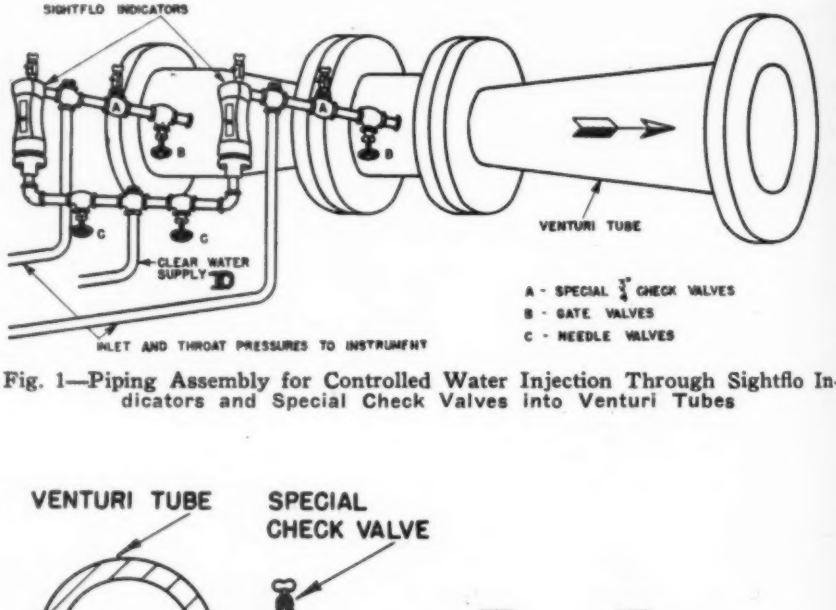


Fig. 1—Piping Assembly for Controlled Water Injection Through Sightflo Indicators and Special Check Valves into Venturi Tubes

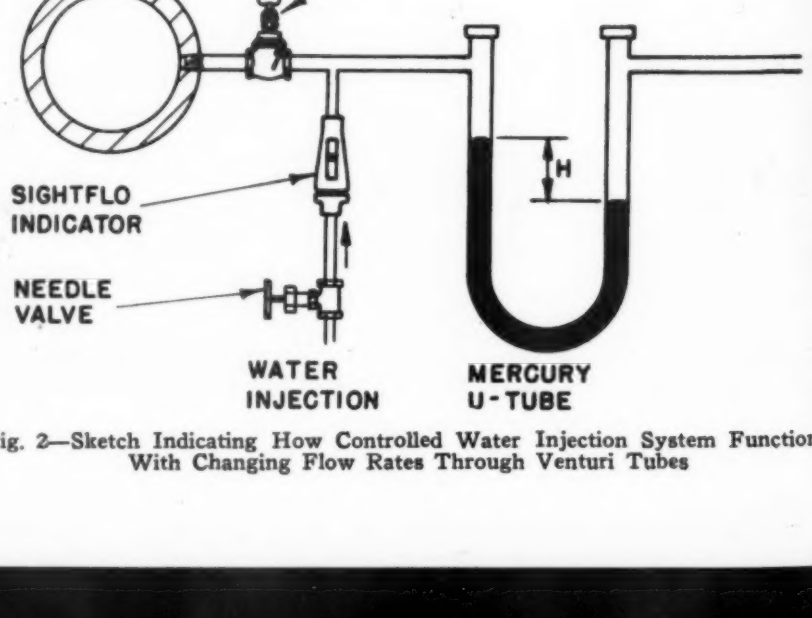


Fig. 2—Sketch Indicating How Controlled Water Injection System Functions With Changing Flow Rates Through Venturi Tubes

cording instrument are no longer required; at best, these tanks furnish only partial protection and are apt to be neglected because of the disagreeable task of keeping them cleaned out.

Figure 1 shows the piping assembly employed. The two pressure pipes (inlet and throat) contain check valves (A and A), gate valves (B and B), needle valves (C and C), a common water supply at D and two Sightflo Indicators, the locations of which are indicated by arrows.

The check valves are of special construction with lapped seats; the Sightflo Indicators are of a new design and permit the injection water rate to be set by observing the height of a rotating float. The reading is taken on an adjacent scale and is usually about one quart per minute through each line, as regulated by the needle valves (C and C). It is not essential that the rate through each be exactly equal as a small difference in the two velocity heads does not affect the true differential between inlet and throat pressures. Once the rates are established, only infrequent resetting is required.

The rate of flow through the Venturi tube may, of course, change from time to time. Suppose the rate decreases; this is accompanied by an increase in pressure at the throat and, referring to Figure 2, the check valve immediately closes to prevent the entrance of sludge into the piping system. At the same time, the pressure from the injection water supply builds up in that branch until the pressure balances the throat pressure and the check valve begins to raise off its seat. The true throat pressure, therefore, is thus established in the U-tube mercury column (illustrating the differential mercury column of a recording instrument) and the differential head H has become the true differential between inlet and throat.

A Year of Service Experience

For about a year there has been an installation of this improved meter for measuring the flow of primary sludge into the digesters of the Cranston, R. I., sewage treatment plant. Figure 3 shows this installation. Here air relays (not shown), mounted below the Venturi tube, transmit the inlet pressures by air to the distant recording instrument. Previous to the installation of the new system, piping connections and air relays had to be cleaned on the average of two or three times a week. Now at no time is cleaning necessary. The answer to whether the meter is performing accurately is found in the routine monthly comparison between the volumetric displacements in the two digesters and the meter readings as shown by the following typical itemization of three months' operation, October 2, 1944 to December 29, 1944. The primary sludge, grease and scum all pass through the 6-in. Venturi (throat diameter 2¾-in.) to two digestion tanks.

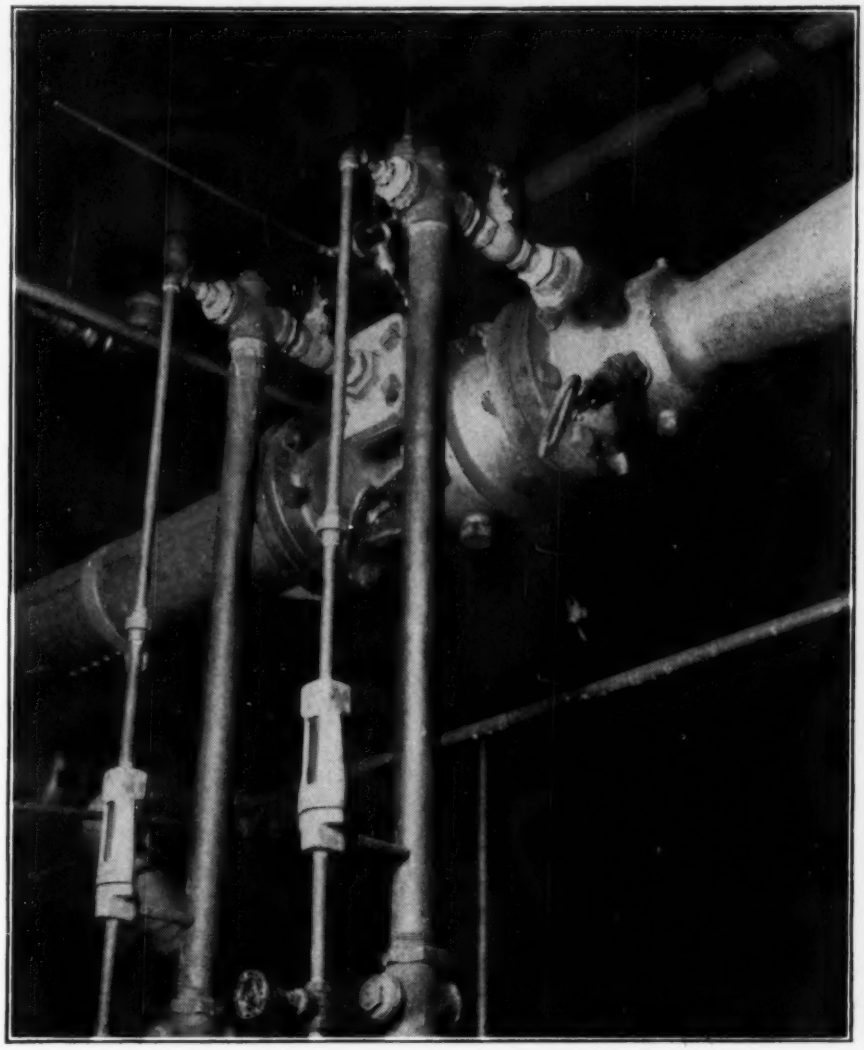


Fig. 3—Installation of Improved Water Injection System in Service on Sludge Meter at Cranston, R. I.

(Note Sightflo Indicators on flushing water lines near bottom of picture.)

The withdrawal from the latter is computed daily by observing the drop in elevation of the floating covers as the result of sludge withdrawal.

The photograph shows the Venturi Tube, Sightflo Indicators, Check Valves, and piping assembly at the Cranston plant. The Air Relays are at a lower elevation.

It will be observed that the Venturi tube is provided with the usual annular pressure chambers at inlet and throat. It is of special significance, therefore, that when the chambers are drained, (only once every six months), they are found to contain but a trace of sediment. In other words, it would seem established that the advantage of multiple vents at the inlet and throat, made possible by the annular rings, can thus be retained even in the measurement of primary sludge.

Primary Sludge		Grease		Scum		Meter Flushing Water		Gallons
695,370	+	33,710	+	133,100	+	50,688	=	912,868
Rainfall, 14.10" (from weather bureau records)								34,500
Displacement of difference in elevation of covers at end and start of period								32,781
								980,149
Total outflow, supernatant and digested sludge								965,646
Difference for the period								14,503

Or 1.5% for the 3 months.

*As computed from changes in tank cover elevations during withdrawals.

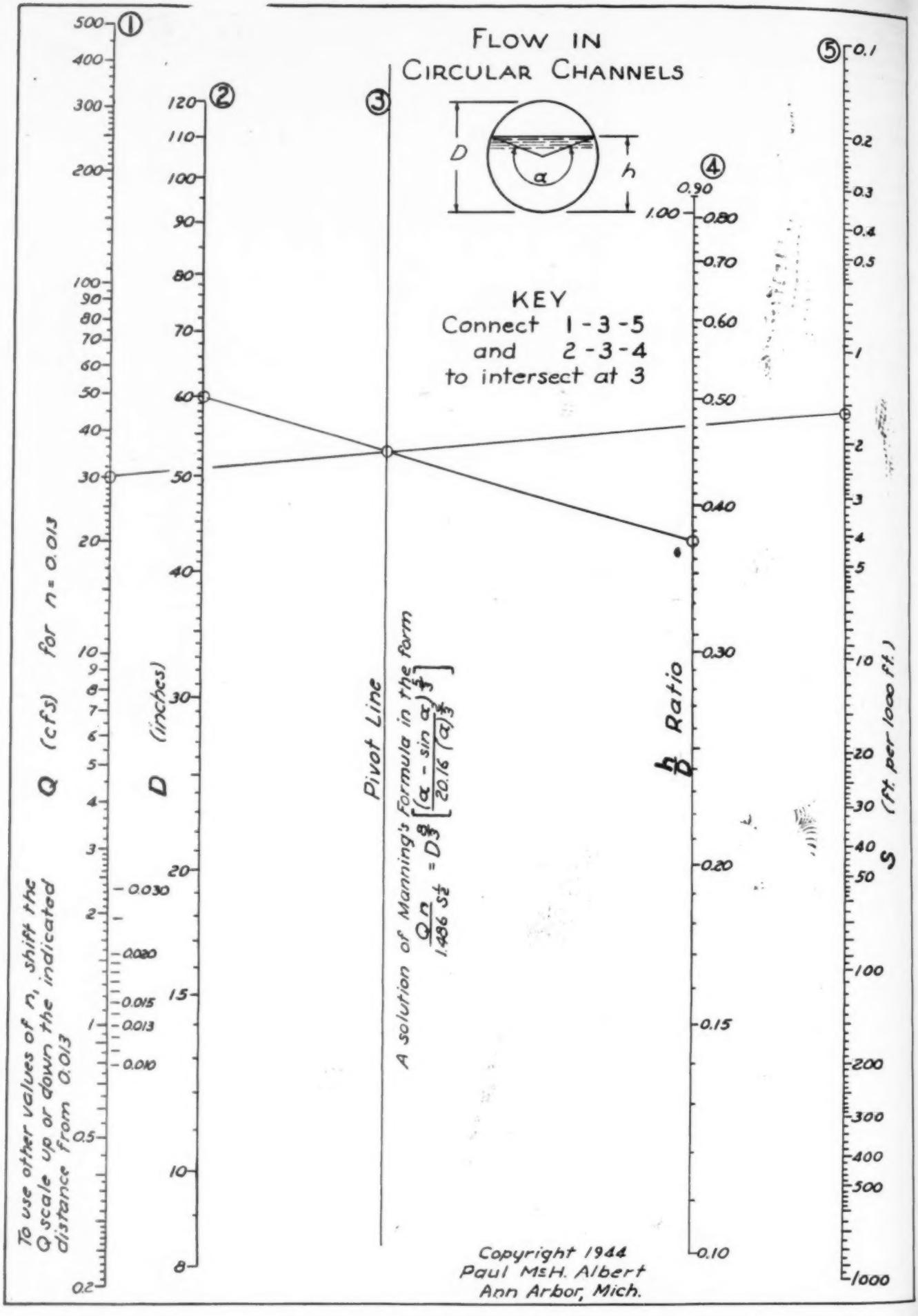

FLOW IN
CIRCULAR CHANNELS
D
h
α
KEY
Connect 1-3-5
and 2-3-4
to intersect at 3
Q (cfs) for n = 0.013
D (inches)
Pivot Line
h/D Ratio
S (ft. per 1000 ft.)
To use other values of n, shift the Q scale up or down the indicated distance from 0.013
A solution of Manning's Formula in the form
Qn / 1.486 S^½ = D^⅜ [(α - sin α) / 20.16 (α)^⅓]^⅝
Copyright 1944
Paul M.H. Albert
Ann Arbor, Mich.

Fig. 1.—Flow in Circular Channels.

FLOW AND DEPTH IN CIRCULAR CHANNELS OR CONDUITS

By
PAUL McH. ALBERT
Shoecraft, Drury and McNamee, Engrs.,
ANN ARBOR, MICH.

FIG 1, "Flow in Circular Channels," introduces an extremely useful solution of Manning's Formula in terms of Q, n, s, diameter and *depth*.

The designer may enter this chart with any of these variables and study the problem. It is no longer necessary to compute the full capacity first, as is currently the practice, and later use the proportional chart or tables to compute fractional flows.

The simplicity of the nomograph is due to the calculation by the writer of a factor which will be called the Circular Depth Factor. The equation shown on the chart was obtained by substituting the elements of a circular section in Manning's Formula and mathematically eliminating the terms area and hydraulic radius. Calculation of the numerical value of the last term of the equation (in brackets), the Circular Depth Factor for definite ratios of h/D from 0.10 to 1.00 produced a table of values which were graduated on the scale (4), the position of each being indicated by its h/D ratio.

Students of hydraulics will recognize the significance of the upper range of this h/D scale, which folds back on itself. The value 0.90 has no practical use and was included purely to complete the scale. It shows graphically that the flow is practically the same at 0.80 and 1.00.

Some Uses for the Nomograph

To extend the range of n, a scale of n values was placed near the bottom of the Q scale, 0.013 being placed opposite 1 cfs. It takes only a few moments to copy one cycle of the Q scale on the edge of a sheet of paper. This may then be placed on any cycle and moved up or down in accordance with the directions shown on the chart.

As the exceptionally large range of the variables includes most of the field of circular channels, only a few of the important uses for the nomograph will be noted.

The Author

The Nomograph Fig. 1 faces this page on left.

The Nomograph Fig. 2 appears on the rear of this page.

The free-board in semi-circular flumes can be determined for any capacity within the size of the flume.

Prefiling of hydraulic gradients is greatly facilitated.

Storage capacities above given flows can be quickly determined.

Discharge, Area and Velocity in Partially Filled Circular Conduits

Fig. 2, "Discharge, Area and Velocity in Partially Filled Circular Sections", solves the two formulas, $Q=AV$ and $A=xD^2$, A being common to both.

Velocity for problems in which Fig. 1 is used can be quickly determined by using the same values of Q, D and h/D. A scale for Velocity Head is placed on one side of the velocity scale (5). In this case it is not necessary to note the area, but merely use that line (3) as the pivot line.

The formula $Q=AV$ can be used for sections that are not circular in shape —square or trapezoidal for instance.*

The formula $A=xD^2$ may be also used to find the volume of horizontal circular cylinders for various depths.

Separately, the two charts offer completely independent equations, but, together, they solve Manning's Formula for all the fundamental variables encountered in circular sections. These are (Q, n, s, D, h/D, A, V) and Velocity Head.

Solution of a Typical Problem

The solution of a typical problem is carried through both charts. To find the depth of flow and velocity when $n=0.013$, $Q=30$ cfs, $D=60$ inches and $s=1.6$ ft. per 1,000 (0.16 per cent).

On Fig. 1, find h/D to be 0.372. Then depth of flow $(L)=0.372\times60=22.3$ inches.

On Fig. 2, using the same Q, D and $h/D=0.372$, find the velocity to be 4.5 feet per second.

*[Ed. Note: Trapezoidal channel problems are easily solved by a nomograph designed by Mr. Albert, which will appear in an early issue.]

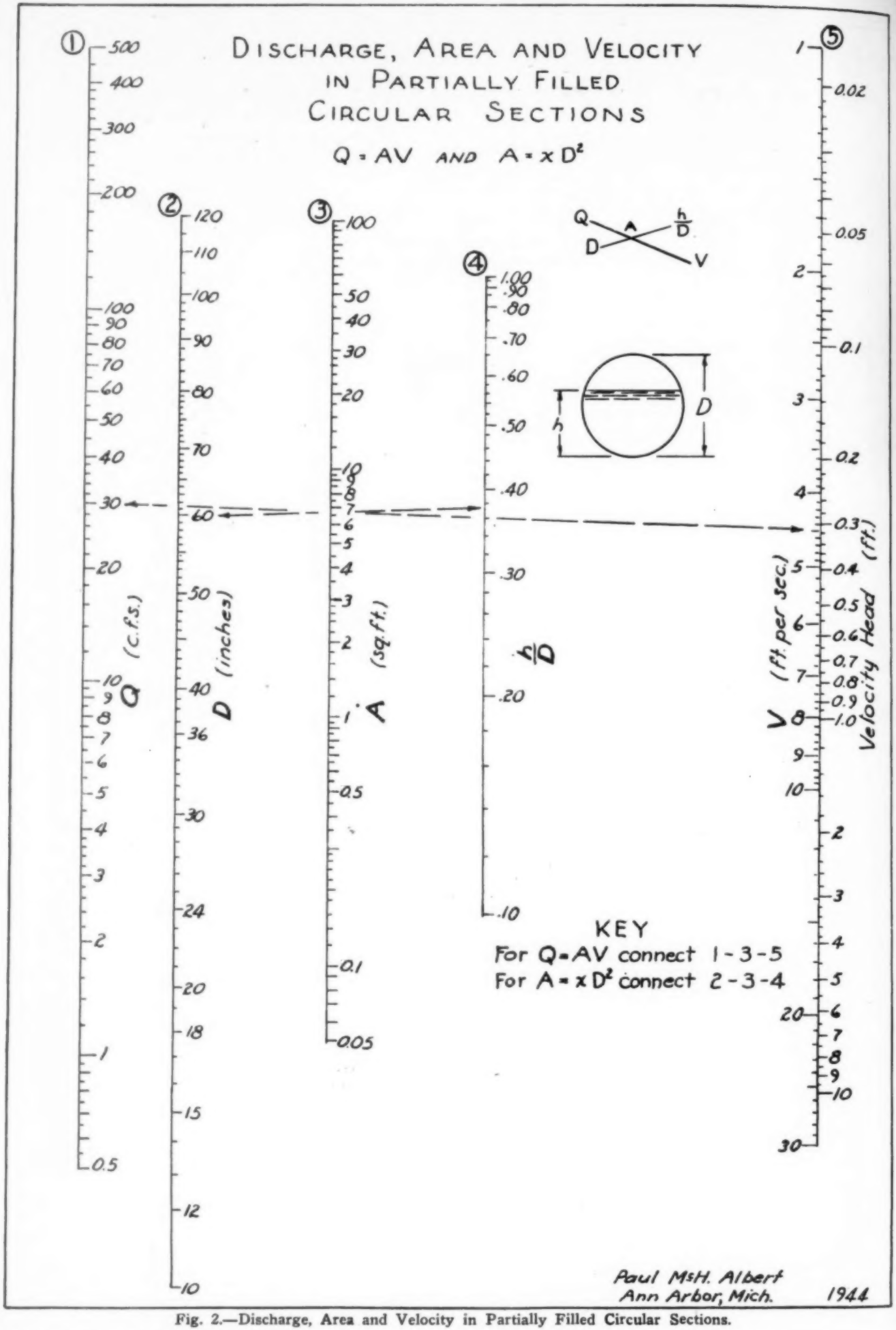


Fig. 2.—Discharge, Area and Velocity in Partially Filled Circular Sections.

NEW ENGLAND S.W.A.'S SPRING MEETING

LAST month we said that one way for an association to maintain its meetings and still not violate ODT restrictions was to hold section meetings. Shortly thereafter we learned

Officers

President
Frank L. Flood
Cons. Engr.
Boston, Mass.

Secretary
LeRoy Van Kleeck
Conn. Dept. Health
Hartford, Conn.

of another way, for we were one of less than fifty persons who journeyed by train to Boston to attend the Spring Meeting of the New England Sewage Works Association. We didn't make use of a hotel room, and according to our count there were less than fifty persons attending that meeting who signed the hotel register.

Now that is not to say that there were less than fifty persons attending the meeting. No, there were more than twice that number who registered for the meeting, but most of them were within commuting distance of Boston. Had there been no travel restrictions, no doubt the registration would have been more than four times fifty. Maybe the NESWA will hold another meeting in the Fall in some other location where many others of its membership of 180 will be able to attend without burdening either the hotels or the railroads.

Porous Tube Air Diffusers

Considering the program that Secy. Le Roy Van Kleeck had lined up, it is apparent that many members of the NESWA stayed away for patriotic reasons for the program was a natural to draw a crowd. Beginning with Frank Roe, of The Carborundum Co., and ending with a group discussion the meeting never lost pace.

Mr. Roe began his talk with a review of the history of porous air diffusers and mentioned, among other things, the early theories calling for small bubble formation, the porous-tube patent of Link-Belt which operates as an air lift to move the bulk of the water, the Chicago Pump diffuser tube, the variation in the location of the plates to reduce the head, and so forth.

There are now some 400 diffused air installations in the country of which nearly fifty per cent utilize porous tubes. In the last five years over 80 per cent of the installations have been tubes rather than plates.

Developments of porous tube equipment have taken two general courses, (1) improvements to increase efficiency and (2) improvements to simplify servicing.

Early designs utilizing tubes suspended parallel with the tank axis usually required more air for a given result than did diffuser plates. This was probably due to the comparatively narrow stream of air bubbles rising above the diffusers and being forced against the tank wall by the circulating current.

The inefficiency of this tube design led to the Chicago Pump Co. development, wherein the tubes are located at right angles to the tank axis to give the so-called wide band of freely rising bubbles, which provides good aeration

Air Diffusion
Frank C. Roe
Carborundum Co.
Perth Amboy, N. J.

Elutriation
Albert L. Genter
Cons. Engr.
Baltimore, Md.

at low air requirements. These tubes also have a control orifice in each tube adaptor to assure proper distribution of air to each tube, thus eliminating individual valves required with early installations.

Improvements in Tubes

One of the first improvements to reduce or simplify diffuser servicing was the change from "fine" to "medium coarse" grade of diffusers, the change applying to both plates and tubes. As to accessibility for cleaning, the tubes obviously were easier to reach, but even this advantage was greatly improved with the introduction of the Chicago Pump Co. "Swing Diffusers", which could be brought right up to the walkway.

Within the past year The Carborundum Co. has developed a new light weight porous tube for these swing diffusers, thereby permitting an increase in the number of tubes that each swing unit can handle.

Advantages of Diffuser Tube Aeration

Mr. Roe listed the following advantages of porous tube diffusers, particularly the wide band type, as opposed to horizontal plate diffusion, pointing out that the comparisons were not being made with the vertical plate diffusers of the Piatt patent, now held by Pacific Flush Tank Co.

1. Contact volume of the rising stream of air bubbles from tubes is more than twice the volume obtained when plates are used.
2. The detention time of the air bubbles in the sewage is greater with tubes than with plates.
3. There is actually a better tank circulation with the wide band aeration obtained from the tube diffusers, the air lift effect being over a wider area so that the entire tank contents are moved more uniformly.
4. The modern tube diffuser system eliminates center coring in aeration tanks, for all practical considerations for a greater volume of tank contents is constantly rolling.
5. The location of the tube diffusers approximately two feet above the tank bottom saves from seven to ten per cent on blower power requirements.
6. The vertical flow of mixed liquor passed suspended diffuser tubes provides a better "wiping" action, resulting in small bubbles while release of bubbles from horizontal plates depends to a large extent on overcoming surface tension.
7. As there is an increase in rate of diffusion from tubes there is little tendency for an increase in the coal-

Supernatant Liquor
L. L. Langford
Pacific Flush Tank
New York City

Operation Charts
W. V. Barry
City Engr.
New Haven, Conn.

escing effect, because the effective area will increase with the increased flow of air due to the slight difference in head between the top and bottom of the tube. With horizontal plates the effective area remains constant and an increased flow of air means increased bubble coalescing effect.

8. In consequence of the above phenomenon, plus the fact that the air stream from modern diffuser tube equipment is unrestricted, rates of air diffusion can be higher from tubes.

For design purposes a 24-in tube, 2½ to 3-in. in dia. will provide 6 cfm. of air, while plate diffusers are designed

More Officers

1st V. P.
George H. Craemer
Supt. Sew. Tr.
Hartford, Conn.

2nd V. P.
Thos. R. Camp
Cons. Engr.
Boston, Mass.

on the basis of only 3 cfm. per sq. ft. maximum.

Diffuser Tube Specification

Mr. Roe believes that present specifications are confusing in that they do not tie in permeability with wet pressure loss which is the important factor, especially with orifice control.

The present dry permeability test is the only practical means of checking the unit in the manufacturers' plant, but permeability is inversely proportional to wet pressure loss and while this gives uniform characteristics, it does not insure that plates made by one factory will have the same characteristics as those made by another. Mr. Roe proposes the following specification:

Permeability and Head Loss

To assure uniform tube operating characteristics the selection of the tubes at the point of manufacture shall be controlled on the basis of the permeability test. The manufacturer shall establish the permeability which he will use to produce tubes which will be acceptable on the basis of the head loss specifications below, and all tubes shall be rejected which do not fall within the maximum allowable deviation of plus or minus 10 per cent of the mean permeability which has been selected.

The diffuser tubes shall have a head loss such that when they are tested submerged in water, with a temperature of 70° plus or minus 2° and with air at a temperature of 70° F. plus or minus 5°, the head loss through the diffuser tube and adapter together with the flow controller or orifice which go to make up a diffuser tube assembly shall not be more than —— in. of water pressure at a flow rate of 4 cu. ft./minute per tube, nor more than —— in. of water pressure at a flow rate of 8 cfm per tube.

The head loss test shall be conducted on ten tubes selected at random from each batch of 1000 tubes which have been accepted from the tube manufacturer on the basis of the permeability control test as outlined above. If the tests indicate that one or more of these tubes are not acceptable on the basis of the head loss determination, 10 per cent of the batch shall be tested and if 10 per cent of these are not acceptable, the entire batch shall be tested for head loss and the additional cost shall be borne by the contractor.

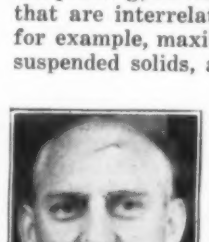
Operation Charts

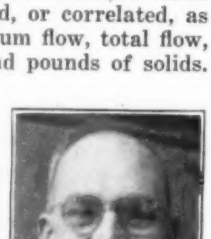
"Human nature comprehends pictures or graphs better than tables or words", according to W. Vincent Barry, City Engineer, New Haven, Conn., who presented a paper on *"Sewage Treatment Plant Operation Charts."* With this idea as his thesis, Mr. Barry presented various kinds and types of charts, and graphs which he has developed and used in the New Haven plant.

The advantage of good records or charts is evident when, as in one case, it was possible to trace the reason for the inability to maintain a chlorine residual at certain hours of the day.

In order to adequately visualize operation of the plant Mr. Barry had plotted step line graphs of the monthly averages of data for four year periods and then had made a template which may be moved to make visible the comparable month in each of four years.

One of the features of these charts is the plotting, on the same chart, of items that are interrelated, or correlated, as for example, maximum flow, total flow, suspended solids, and pounds of solids.





Discussion

L. H. Chamberlain
Amer. Well Wks.
New York City

Joseph L. Doman
San. Engr.
Greenwich, Conn.

On another sheet are sludge pumped, per cent dry solids, ferric chloride and lime dosages, filter yield, moisture in sludge cake, and total pounds of sludge cake.

From these graphs it is possible to see at once whether operation has been proper and efficient, and to make corrections in plant control if it has not.

Small Sludge Elutriation Plants

If vacuum filtration of sludge is advisable, so too is elutriation of sludge, regardless of plant size, according to Albert L. Genter, Cons. Engr., Baltimore, who talked on "Small Sludge Elutriation plants".

Pointing out that the same elutriation plant will serve a population of 20,000 if operated 20 per cent of the time, 40,000 if operated 40 per cent of the time, and 70,000 if operated 70 per cent of the time, Mr. Genter, said that the flexibility of capacity was important to the design, and made it easy to plan for expansion if needed.

The economic returns from elutriation are dependent on the price of chemicals in the locality, the type of sludge, and the size of plant required.

Factors to be considered in planning for elutriation are.

1. Kinds of digested sludge.
2. The washing method, whether counter current, single or two stage.
3. Continuous or intermittent operation.

Metering of sludge and wash water is important, but Venturi meters are not for small plants. A volumetric feeder is preferrable for feeding ferric chloride. If possible combine two stage counter current for the best results. Install tanks near the vacuum filters to save piping.

Mr. Genter showed several slides depicting how it is possible to obtain flexible operation of sludge elutriation in small plants and the many advantages accruing therefrom.

Symposium on Supernatant Liquor

Leading off with a paper, written by C. V. Erickson, Research Dept. of Pacific Flush Tank Co., Leonard L. Langford, Eastern Sales Mgr. of the Company, opened the afternoon symposium on *"Treatment and Disposal of Digestion Tank Supernatant Liquor."*

Supernatant liquor being the liquor that must be displaced from a digestion tank when sludge is pumped into it, then it is obvious that the amount of such liquor will depend on the concentration of the sludge pumped. A two per cent solids concentration of mixed primary and activated sludge would have a volume three times as great as a six per cent sludge.

Control of the duration and frequency of raw sludge pumping can accomplish much to limit the amount of excess liquid entering the digestion tank. From an ideal viewpoint, frequent pumping of small amounts of thick sludge is desirable, but practically it is better to remove as much primary sludge as possible to prevent

More Discussion

Dr. A. J. Fischer
The Dorr Co.
New York City

Charles H. Copely
Supt. Sew. Tr.
New Haven, Conn.

septicity. Therefore attempts to limit water entering the digester will of necessity follow an intermediate procedure between these two. Frequent sampling during pumping is advisable to ascertain the consistency of the sludge being pumped.

As an example of the effect of control, Mr. Langford cited Aurora, Ill., where an increase of sludge concentration

from 3.5 to 5.2 per cent resulted in an increase from 38 to 49 days in the displacement period in the digester. Concentration units between the digester and the settling units are an advantage in thickening raw sludge.

Definition of Supernatant Liquor

Mr. Langford indicated that there is some disagreement as to what supernatant liquor is, particularly inasmuch as the dictionary definition doesn't seem to exactly fit the conditions which exist in the digestion tank. Messrs. Langford and Erickson object to the common viewpoint that supernatant liquor is "anything taken out of a digestion tank that is not sludge, scum, or gas," and they look sidewise at the definition which says that "supernatant liquor is the layer between the sludge and scum." Definition according to characteristics of the liquor has both advantages and disadvantages, but the idea that supernatant liquor is the thinnest liquid in the tank is difficult to reconcile with conditions.

These authors propose a definition which defines supernatant liquor as having the following characteristics:

1. Total solids content less than 10,000 ppm.
2. Not less than 60 per cent reduction in volatile solids content of the raw sludge on the dry basis, or having not more than 50 per cent volatile matter in the solids.
3. Volume of suspended solids occupying not more than 50 per cent of the original volume after one hour's quiescent settling.

(While this reporter is a purest in the matter of many definitions, he can not forget that as far as the operator is concerned it matters little what you call it, how you define it, or what is in the liquor—if one pumps sludge into a digester, there must be some liquor removed. How much and what is in it depends on the time, the place, and the sludge, and if an operator's records have a column for supernatant liquor, he is not likely to find it either feasible or convenient to run tests to ascertain whether the liquid meets an arbitrary definition. From a purest's point of view it is far better to call the liquid simply "digester overflow liquor" for strictly speaking that is what it is, regardless of what it contains.)

In the matter of removing this supernatant or digester overflow liquor, Langford suggests that multiple draw-off pipes are better than a single outlet, but even this is not flexible enough. Multiple digesters likewise reduce the solids content of the final supernatant liquor. Best solution to the withdrawal problem is a supernatant selector, a slotted vertical withdrawal pipe which allows continuous withdrawal at low rates and from locations where the solid content of the liquor is the lowest. Control of the withdrawal is by orifice and sight glass and at one plant in a 95 ft. digester, the rate is as low as 27 gpm.

Treatment of Supernatant Liquor

Among the various methods of treating supernatant liquor Langford and Erickson list the following: Return to the treatment process, usually ahead of the primary units; discharge to drying beds; chemical coagulation and settling; sedimentation (with chlorination to prevent floating solids); aeration; centrifuging; and lagooning.

Smiling Registrants

W. S. Wise
State Water Comm.
Hartford, Conn.

W. S. Snow
State Water Comm.
Hartford, Conn.

Paul J. Cerny
Pacific Flush Tank
New York City
(Back in civies)

The authors propose an effective scheme of treatment by atomized aeration and settling. Aeration is accomplished by a low vacuum in the top of a unit which causes the liquor to be sucked up through tuyeres with air and atomized as it is discharged into the upper part of the tank or apparatus. Operating data show from 50 to 90 per cent removal of suspended solids between the ranges of 2000 to 10,000 ppm. in this treatment. At the same time the oxygen demand of the liquor is reduced.

Discussion

L. H. Chamberlain, Eastern District Mgr. of the American Well Works, in discussing the subject said that there are three characteristics which make supernatant liquor hard to treat. These are a high immediate or shock B.O.D., suspended solids that do not settle easily, and a seeding or septifying action. This latter effect may be shown by a methylene blue stability test. Where raw sewage has a stability of 4.75 hr., a mixture of raw and untreated supernatant liquor has a stability of only one hr., but if the supernatant liquor is aerated, then the stability of the mixture is 4.5 hr.

Mr. Chamberlain showed some slides of installations employing recirculation of the liquor through ⅜in. (particle size) anthracite bed. Back washing to remove all but a seeding quantity of the removed solids keeps the bed in good operation. Performance of the aeration bed depends on the surface area, that is, it varies inversely as the diameter of the particle. Small size particle, (i.e. greater surface) is feasible when the filter is backwashed with water.

Dr. Anthony J. Fischer, Development Engr., The Dorr Co., said that many of the supernant liquor problems in a plant were caused by uncontrollable factors so far as the operator is concerned. These include digesters designed too small and high volatile content in the sludge. As to controllable factors, Dr. Fischer mentioned agitation caused by too frequent pumping or improper location of the inlet too near the drawoff (this is a design feature not controllable by the operator).

In general the solids concentration of sludge from activated sludge is lower than in trickling filter sludge which is lower than primary sludge all of which means that volume of supernatant liquor must be inverse. To the methods of handling supernatant liquor already mentioned should be added, the elimininations of supernatant liquor, handling on contact beds, and handling on trickling filters.

For the latter method one needs but a small filter plant, but whether treated or not, (except for settling of the solids) the overall effect of supernant liquor on the final B.O.D. is so small as to be almost negligible. Therefore Dr. Fischer recommends storage and settling alone as sufficient treatment.

Joseph Doman, San. Engr., Dep't of Public Works, Greenwich Conn., reported on the results of remodeling to handle the supernatant liquor problem at the two plants in Greenwich. At both plants the sedimentation units were inadequate, and rather than add to these, the designing engineers provided plain sedimentation with sludge removal to digesters. The old settling tanks were used for settling the decanted supernatant liquor, but could also be used for storing excess sludge from the digesters if and when it needed further digestion.

Good results and effluents are obtained at both plants from the settling out of the supernatant solids, and the settleable solids in the effluents are usually less than 1 ml. per liter. A few tests indicate the suspended solids content to be approximately 400 ppm. (or roughly twice that in the raw sewage).

At old Greenwich the supernatant liquor after settling is returned to the settling tanks without deleterious effect, although during the chlorinating season it increases the chlorine demand while flowing through the tank.

At the Grass Island plant, grades are such that pumping would have been necessary to return the supernatant liquor to the primary settling tanks or the chlorine contact tank. Rather than install pumps and add to the construction costs, the supernatant liquor is discharged by gravity into the effluent outfall sewer. The digester is decanted the first thing each morning so that the liquor will be mixed with the relatively clear night flow still going through the tanks. During the chlorinating season the residual chlorine is approx. 1 ppm. The settled supernatant liquor amounts to approximately 4000 g. per mil gal. of flow, and it is believed that this material is fairly well disinfected by the excess chlorine in the sewage effluent before it reaches tide water. (G.E.S.)

G.C.H. N.W.N.

FREE FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME

SEC.-FT. X .646317 = M.G.D. M.G.D. X 1.54723 = SEC.-FT.

SEC.-FT. X 448.831 = G.P.M. G.P.M. X .002228 = SEC.-FT.

THROAT WIDTH

HEAD		6"			9"			12"			18"			24"		
FT.	IN.	SEC-FT	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D	SEC-FT.	G.P.M.	M.G.D	SEC.FT	G.P.M	M.G.D.
0.10	1 3/16	0.05	22.4	0.032	0.09	40.4	.0580									
0.11	1 5/16	0.06	26.9	0.039	0.10	44.9	.0650									
0.12	1 7/16	0.07	31.4	0.045	0.12	53.8	.0775									
0.13	1 9/16	0.08	35.9	0.052	0.14	62.8	.0905									
0.14	1 11/16	0.09	40.4	0.058	0.15	67.3	.0970									
0.15	1 13/16	0.10	44.9	0.065	0.17	76.3	.1100									
0.16	1 15/16	0.11	49.4	0.071	0.19	85.2	.1230									
0.17	2 1/16	0.12	53.8	0.077	0.20	89.8	.1290									
0.18	2 3/16	0.14	62.8	0.090	0.22	98.7	.1420									
0.19	2 1/4	0.15	67.3	0.097	0.24	107.7	.1550									
0.20	2 5/16	0.16	71.6	0.103	0.26	116.9	.1680	0.35	157.1	0.226	0.51	229.0	0.330	0.66	296.3	0.426
0.21	2 1/2	0.18	80.7	0.116	0.28	125.7	.1810	0.37	166.1	0.239	0.55	247.0	0.355	0.71	318.7	0.458
0.22	2 7/16	0.19	85.2	0.123	0.30	134.6	.1940	0.40	179.5	0.259	0.59	265.0	0.381	0.77	345.6	0.498
0.23	2 3/8	0.20	89.8	0.129	0.32	143.6	.2070	0.43	193.0	0.278	0.63	283.0	0.407	0.82	368.0	0.530
0.24	2 5/8	0.22	98.7	0.142	0.35	157.1	.2260	0.46	206.5	0.297	0.67	301.0	0.433	0.88	395.0	0.569
0.25	3	0.23	103.3	0.149	0.37	166.1	.2390	0.49	219.9	0.316	0.71	318.7	0.458	0.93	417.5	0.601
0.26	3 1/8	0.25	112.2	0.162	0.39	175.1	.2520	0.51	229.0	0.330	0.76	341.1	0.491	0.99	444.3	0.640
0.27	3 1/4	0.26	116.9	0.168	0.41	184.0	.2650	0.54	242.3	0.349	0.80	359.0	0.517	1.05	471.3	0.679
0.28	3 3/8	0.28	125.7	0.181	0.44	197.5	.2840	0.58	260.3	0.374	0.85	381.5	0.549	1.11	498.2	0.717
0.29	3 1/2	0.29	130.2	0.187	0.46	206.5	.2970	0.61	274.0	0.394	0.90	404.0	0.582	1.18	530.0	0.763
0.30	3 5/8	0.31	139.2	0.203	0.49	219.9	.3160	0.64	287.3	0.414	0.94	422.0	0.607	1.24	556.6	0.801
0.31	3 3/4	0.32	143.6	0.207	0.51	229.0	.3300	0.68	305.2	0.439	0.99	444.3	0.640	1.30	583.4	0.840
0.32	3 7/16	0.34	152.6	0.220	0.54	242.3	.3490	0.71	318.7	0.458	1.04	466.8	0.672	1.37	615.0	0.886
0.33	3 7/8	0.36	161.5	0.233	0.56	251.3	.3620	0.74	332.0	0.478	1.09	489.0	0.704	1.44	646.0	0.930
0.34	4 1/8	0.38	170.5	0.246	0.58	265.0	.3810	0.77	345.6	0.498	1.14	512.0	0.737	1.50	673.2	0.969
0.35	4 1/4	0.39	175.1	0.252	0.62	278.0	.4010	0.80	359.0	0.517	1.19	534.0	0.769	1.57	705.0	1.015
0.36	4 3/8	0.41	184.0	0.265	0.64	287.3	.4140	0.84	377.0	0.543	1.25	561.0	0.808	1.64	736.0	1.060
0.37	4 1/16	0.43	193.0	0.278	0.67	301.0	.4330	0.88	395.0	0.569	1.30	583.4	0.840	1.72	772.0	1.111
0.38	4 5/16	0.45	201.9	0.291	0.70	314.0	.4520	0.92	412.9	0.594	1.36	610.0	0.879	1.79	803.4	1.156
0.39	4 7/16	0.47	210.9	0.304	0.73	327.6	.4720	0.95	426.0	0.614	1.41	633.0	0.911	1.86	835.0	1.202
0.40	4 1/2	0.48	215.5	0.310	0.76	341.1	.4912	0.99	444.3	0.640	1.47	659.0	0.950	1.93	866.0	1.247
0.41	4 5/8	0.50	224.4	0.323	0.78	350.0	.5040	1.03	462.0	0.666	1.53	686.0	0.989	2.01	902.0	1.299
0.42	4 3/4	0.52	233.3	0.336	0.81	363.5	.5240	1.07	480.0	0.692	1.58	709.0	1.021	2.09	938.0	1.350
0.43	4 7/8	0.54	242.3	0.349	0.84	377.0	.5430	1.11	498.1	0.717	1.64	736.0	1.060	2.16	969.0	1.396
0.44	4 15/16	0.56	251.3	0.362	0.87	390.4	.5620	1.15	516.0	0.743	1.70	763.0	1.098	2.24	1005	1.447
0.45	5	0.58	260.3	0.375	0.90	404.0	.5820	1.19	534.0	0.769	1.76	790.0	1.137	2.32	1041	1.499
0.46	5 1/16	0.61	274.0	0.394	0.94	422.0	.6075	1.23	552.0	0.795	1.82	816.0	1.176	2.40	1077	1.551
0.47	5 1/8	0.63	283.0	0.407	0.97	435.0	.6270	1.27	570.0	0.821	1.88	843.0	1.215	2.48	1113	1.602
0.48	5 3/16	0.65	292.0	0.420	1.00	448.8	.6460	1.31	588.0	0.847	1.94	870.0	1.254	2.57	1153	1.661
0.49	5 5/16	0.67	301.0	0.433	1.03	462.0	.6660	1.35	606.0	0.872	2.00	898.0	1.293	2.65	1189	1.712
0.50	6	0.69	310.0	0.446	1.06	475.7	.6850	1.39	624.0	0.898	2.06	925.0	1.331	2.73	1225	1.764
0.51	6 1/16	0.71	318.7	0.459	1.10	493.7	.7109	1.44	646.0	0.930	2.13	956.0	1.376	2.82	1266	1.822
0.52	6 1/8	0.73	327.6	0.472	1.13	507.0	.7300	1.48	664.0	0.956	2.19	983.0	1.415	2.90	1301	1.875
0.53	6 3/16	0.76	341.1	0.491	1.16	521.0	.7500	1.52	682.0	0.982	2.25	1010	1.454	2.99	1342	1.932
0.54	6 1/2	0.78	350.0	0.504	1.20	538.0	.7760	1.57	703.0	1.015	2.32	1041	1.499	3.08	1382	1.990
0.55	6 5/16	0.80	359.0	0.517	1.23	552.0	.7950	1.62	727.0	1.047	2.39	1073	1.545	3.17	1422	2.049
0.56	6 3/8	0.82	368.0	0.530	1.26	565.5	.8140	1.66	745.0	1.073	2.45	1099	1.583	3.26	1463	2.107
0.57	6 7/16	0.85	381.5	0.549	1.30	583.4	.8400	1.70	763.0	1.098	2.52	1131	1.628	3.35	1504	2.165
0.58	6 1/2	0.87	390.4	0.562	1.33	597.0	.8600	1.75	786.0	1.131	2.59	1163	1.674	3.44	1544	2.224
0.59	7 1/16	0.89	399.5	0.575	1.37	615.0	.8860	1.80	808.0	1.163	2.66	1194	1.719	3.53	1585	2.282
0.60	7 1/8	0.92	412.9	0.595	1.40	628.0	.9050	1.84	826.0	1.189	2.73	1225	1.764	3.62	1625	2.340
0.61	7 1/4	0.94	422.0	0.608	1.44	646.0	.9300	1.88	843.0	1.215	2.80	1257	1.809	3.72	1670	2.404
0.62	7 1/16	0.97	435.0	0.627	1.48	664.0	.9560	1.93	866.0	1.247	2.87	1290	1.855	3.81	1710	2.463
0.63	7 3/16	0.99	444.3	0.640	1.51	678.0	.9760	1.98	889.0	1.280	2.95	1324	1.907	3.91	1755	2.527
0.64	7 1/16	1.02	457.8	0.659	1.55	696.0	1.002	2.03	911.0	1.312	3.02	1355	1.952	4.01	1800	2.592
0.65	7 5/16	1.04	466.8	0.672	1.59	714.0	1.028	2.08	934.0	1.345	3.09	1387	1.997	4.11	1845	2.656
0.66	7 1/16	1.07	480.0	0.692	1.63	732.0	1.054	2.13	956.0	1.376	3.17	1422	2.049	4.20	1885	2.714
0.67	8 1/16	1.10	493.7	0.711	1.66	745.0	1.073	2.18	978.0	1.409	3.24	1454	2.094	4.30	1930	2.780
0.68	8 3/16	1.12	503.0	0.724	1.70	763.0	1.098	2.23	1001	1.441	3.31	1486	2.140	4.40	1975	2.844
0.69	8 1/4	1.15	516.0	0.743	1.74	781.0	1.125	2.28	1024	1.474	3.39	1522	2.191	4.50	2020	2.908
0.70	8 5/16	1.17	525.1	0.756	1.78	799.0	1.151	2.33	1046	1.506	3.46	1553	2.236	4.60	2065	2.973

HEAD		6"			9"			12"			18"			24"		
FT	IN	SEC FT	G P M	M G D	SEC.FT	G.P.M.	M G D	SEC.FT	G.P.M.	M.G.D	SEC-FT.	G.P.M.	M.G.D.	SEC.FT	G.P.M.	M.G.D.
0.71	8 1/2	1.20	538	0.776	1.82	816	1.176	2.38	1068	1.538	3.54	1590	2.288	4.70	2111	3.038
0.72	8 5/16	1.23	552	0.795	1.86	835	1.202	2.43	1091	1.571	3.62	1625	2.340	4.81	2159	3.110
0.73	8 3/4	1.26	566	0.814	1.90	853	1.228	2.48	1113	1.602	3.69	1656	2.385	4.91	2204	3.174
0.74	8 7/16	1.28	575	0.827	1.94	870	1.254	2.53	1136	1.635	3.77	1692	2.437	5.02	2253	3.245
0.75	9	1.31	588	0.847	1.98	889	1.280	2.58	1158	1.667	3.85	1728	2.488	5.12	2300	3.310
0.76	9 1/16	1.34	601	0.866	2.02	907	1.306	2.63	1182	1.700	3.93	1764	2.540	5.23	2347	3.380
0.77	9 1/4	1.36	610	0.879	2.06	925	1.331	2.68	1203	1.732	4.01	1800	2.592	5.34	2397	3.451
0.78	9 3/16	1.39	624	0.898	2.10	943	1.357	2.74	1230	1.771	4.09	1836	2.643	5.44	2442	3.516
0.79	9 5/16	1.42	637	0.918	2.14	960	1.383	2.80	1257	1.809	4.17	1872	2.695	5.55	2491	3.587
0.80	9 3/8	1.45	651	0.937	2.18	978	1.409	2.85	1280	1.842	4.26	1912	2.753	5.66	2540	3.658
0.81	9 7/16	1.48	664	0.957	2.22	996	1.435	2.90	1301	1.875	4.34	1948	2.805	5.77	2597	3.730
0.82	9 1/16	1.50	673	0.970	2.27	1019	1.467	2.96	1329	1.913	4.42	1984	2.857	5.88	2639	3.800
0.83	9 15/16	1.53	686	0.989	2.31	1036	1.493	3.02	1355	1.952	4.50	2020	2.908	6.00	2692	3.878
0.84	10 1/16	1.56	700	1.008	2.35	1054	1.518	3.07	1377	1.984	4.59	2060	2.967	6.11	2742	3.950
0.85	10 3/16	1.59	714	1.028	2.39	1073	1.545	3.12	1400	2.017	4.67	2096	3.018	6.22	2791	4.020
0.86	10 5/16	1.62	727	1.047	2.44	1095	1.577	3.18	1427	2.055	4.76	2136	3.076	6.33	2841	4.091
0.87	10 7/16	1.65	741	1.066	2.48	1113	1.602	3.24	1454	2.094	4.84	2171	3.128	6.44	2891	4.162
0.88	10 9/16	1.68	754	1.085	2.52	1131	1.628	3.29	1476	2.126	4.93	2212	3.186	6.56	2944	4.240
0.89	10 11/16	1.71	768	1.105	2.57	1153	1.661	3.35	1504	2.165	5.01	2248	3.238	6.68	2998	4.318
0.90	10 13/16	1.74	781	1.125	2.61	1171	1.686	3.41	1530	2.203	5.10	2289	3.296	6.80	3052	4.394
0.91	10 15/16	1.77	794	1.144	2.66	1194	1.720	3.46	1553	2.236	5.19	2329	3.354	6.92	3105	4.473
0.92	11 1/16	1.81	812	1.169	2.70	1212	1.745	3.52	1580	2.275	5.28	2370	3.413	7.03	3155	4.543
0.93	11 3/16	1.84	826	1.189	2.75	1234	1.777	3.56	1606	2.313	5.37	2410	3.470	7.15	3209	4.621
0.94	11 1/16	1.87	839	1.208	2.79	1252	1.803	3.64	1633	2.352	5.46	2450	3.529	7.27	3263	4.696
0.95	11 7/16	1.90	853	1.228	2.84	1274	1.835	3.70	1661	2391	5.55	2491	3.587	7.39	3316	4.777
0.96	11 1/2	1.93	866	1.247	2.88	1292	1.862	3.76	1687	2.430	5.64	2531	3.645	7.51	3370	4.853
0.97	11 9/16	1.97	884	1.273	2.93	1315	1.894	3.82	1714	2.468	5.73	2572	3.703	7.63	3425	4.930
0.98	11 5/8	2.00	898	1.293	2.98	1337	1.926	3.88	1741	2.510	5.82	2612	3.762	7.75	3476	5.009
0.99	11 7/16	2.03	911	1.312	3.02	1355	1.952	3.94	1768	2.547	5.91	2653	3.820	7.88	3537	5.090
1.00	12	2.06	925	1.331	3.07	1377	1.984	4.00	1795	2.585	6.00	2692	3.878	8.00	3590	5.170
1.01	12 1/16	2.09	938	1.350	3.12	1400	2.017	4.06	1822	2.624	6.09	2733	3.936	8.12	3645	5.248
1.02	12 1/8	2.12	952	1.370	3.17	1422	2.049	4.12	1849	2.662	6.19	2776	4.000	8.25	3703	5.332
1.03	12 3/16	2.16	969	1.396	3.21	1440	2.074	4.18	1876	2.701	6.28	2818	4.059	8.38	3761	5.416
1.04	12 1/4	2.19	983	1.415	3.26	1463	2.107	4.25	1908	2.747	6.37	2859	4.117	8.50	3815	5.494
1.05	12 5/16	2.22	996	1.435	3.31	1486	2.140	4.31	1934	2.786	6.47	2904	4.182	8.63	3873	5.578
1.06	12 3/8	2.26	1014	1.460	3.36	1508	2.172	4.37	1961	2.824	6.56	2944	4.240	8.76	3932	5.662
1.07	12 7/16	2.29	1027	1.480	3.40	1526	2.197	4.43	1988	2.863	6.66	2989	4.304	8.88	3986	5.740
1.08	12 1/16	2.32	1041	1.500	3.45	1548	2.230	4.50	2020	2.908	6.75	3030	4.362	9.01	4044	5.823
1.09	13 1/16	2.36	1060	1.525	3.50	1571	2.262	4.56	2047	2.947	6.85	3075	4.427	9.14	4102	5.907
1.10	13 3/16	2.40	1077	1.551	3.55	1594	2.295	4.62	2074	2.986	6.95	3119	4.492	9.27	4161	5.991
1.11	13 5/16	2.45	1091	1.571	3.60	1616	2.327	4.68	2101	3.025	7.04	3160	4.550	9.40	4220	6.075
1.12	13 7/16	2.46	1104	1.590	3.65	1638	2.360	4.75	2132	3.070	7.14	3205	4.614	9.54	4282	6.165
1.13	13 9/16	2.50	1122	1.616	3.70	1661	2.391	4.82	2164	3.115	7.24	3250	4.680	9.67	4340	6.250
1.14	13 11/16	2.53	1136	1.635	3.75	1683	2.424	4.88	2190	3.154	7.34	3294	4.744	9.80	4399	6.334
1.15	13 13/16	2.57	1153	1.661	3.80	1706	2.456	4.94	2217	3.193	7.44	3339	4.810	9.94	4461	6.424
1.16	13 15/16	2.60	1167	1.681	3.85	1728	2.490	5.01	2248	3.236	7.54	3384	4.873	10.1	4570	6.528
1.17	14 1/16	2.64	1185	1.706	3.90	1750	2.521	5.08	2280	3.283	7.64	3429	4.940	10.2	4581	6.593
1.18	14 3/16	2.68	1203	1.732	3.95	1773	2.553	5.15	2311	3.329	7.74	3474	5.003	10.3	4623	6.657
1.19	14 1/16	2.71	1217	1.752	4.01	1800	2.592	5.21	2338	3.367	7.84	3519	5.067	10.5	4713	6.786
1.20	14 5/16	2.75	1234	1.777	4.06	1822	2.624	5.28	2370	3.413	7.94	3564	5.132	10.6	4760	6.851
1.21	14 1/2	2.78	1248	1.797	4.11	1845	2.656	5.34	2397	3.451	8.05	3613	5.203	10.8	4850	6.980
1.22	14 7/16	2.82	1266	1.823	4.16	1867	2.689	5.41	2428	3.497	8.15	3658	5.267	10.9	4892	7.045
1.23	14 3/4	2.86	1284	1.848	4.22	1894	2.728	5.48	2460	3.542	8.25	3703	5.332	11.0	4940	7.110
1.24	14 9/16	2.89	1297	1.867	4.27	1917	2.760	5.55	2491	3.587	8.36	3752	5.403	11.2	5027	7.240
1.25	15	2.93	1315	1.894	4.32	1939	2.793	5.62	2522	3.632	8.46	3800	5.468	11.3	5072	7.304
1.26	15 1/16	2.97	1333	1.920	4.37	1961	2.824	5.69	2554	3.678	8.56	3842	5.533	11.5	5162	7.433
1.27	15 1/4	3.01	1350	1.945	4.43	1988	2.863	5.76	2585	3.723	8.67	3892	5.603	11.6	5210	7.497
1.28	15 3/16	3.04	1364	1.965	4.48	2011	2.896	5.82	2612	3.762	8.77	3936	5.666	11.7	5251	7.562
1.29	15 5/16	3.08	1382	1.991	4.53	2033	2.928	5.89	2644	3.807	8.86	3986	5.740	11.9	5341	7.691
1.30	15 3/8	3.12	1400	2.017	4.59	2060	2.967	5.96	2675	3.852	8.99	4035	5.810	12.0	5396	7.756
1.31	15 5/16	3.16	1418	2.042	4.64	2085	3.000	6.03	2710	3.900	9.09	4080	5.875	12.2	5478	7.885

FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUMES

By N. W. NESTER and G. C. HANES
Captain San. Engr.
Corps of Engineers, U. S. Army*

THE accompanying table has been prepared to bring together in one place, significant data for use in the determination of free-flow discharge for Parshall measuring flumes of 5 different sizes. This particular chart has found effective use in the 9th Service Command Area where many Parshall flumes are installed.

It has proved helpful to field engineers of the Headquarters office as well as to plant operators, and while the range of throat widths has been limited to those in this Command area, the data should be useful to any sewage plant having that size Parshall flume.

The basic data for this table were obtained from Farmers' Bulletin No. 1683, published by the U. S. Dept. of Agric. and titled "Measuring Water in Irrigation Channels" by R. L. Parshall, Sr. Irrigation Engr., Div. of Irrigation, Soil Conservation Service.

The table has proved useful as a check on indicating and recording flow meters that have been installed on Parshall flumes. Frequently, discrepancies may be found, as for example, a meter installed on a flume with a throat width larger or smaller than that for which it was designed; or the wrong meter chart may be used.

Testing Float Controlled Meters

In testing the common float-controlled meter, the following method has proved simple but satisfactory. The float is disconnected and a point on the cable is moved by hand from the position where the meter indicates zero flow to the maximum for which the flume was designed, in increments of one inch or one-tenth foot. The point is then moved down the scale so that the meter again indicates zero. The corresponding readings on the meter for each point on the scale are noted. This procedure is repeated several times in order to obtain an average.

The results of these observations are plotted on a graph containing a curve for the throat width (made from data in the accompanying table) on which the meter mechanism is installed. Any discrepancy of the observed data from the correct curve is readily apparent. If the error is large, it is well to plot the curve of another flume of larger or smaller throat width on the same graph. This will usually indicate the design curves of the meter and corrections may be made accordingly.

*9th Service Command, Ft. Douglas, Utah.

Braidech to Direct Fire Underwriters Research

As of June 1, Mathew M. Braidech, Prof. of Industrial and Sanitary Chemistry at Case School of Applied Science, Cleveland, became Director of Research of the National Board of Fire Underwriters.

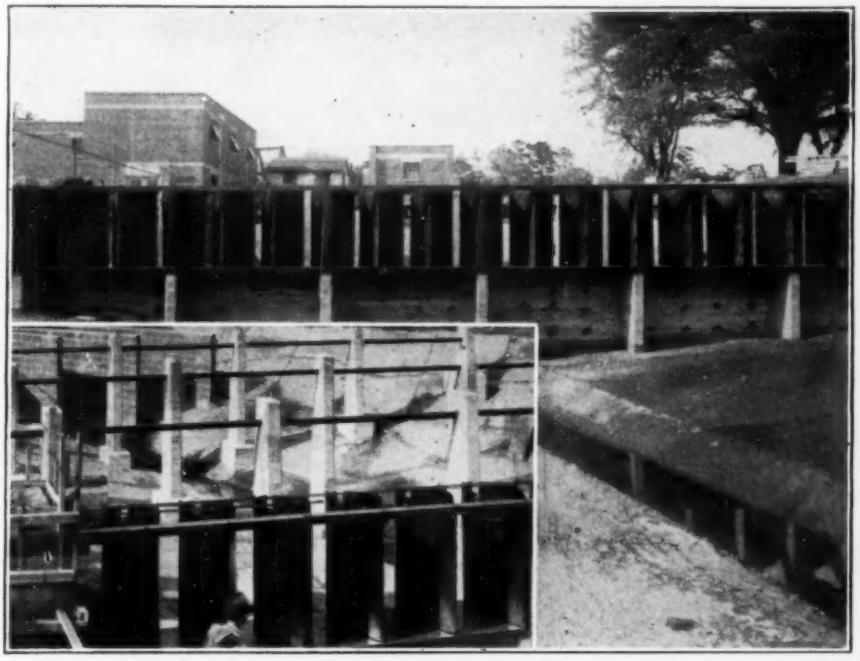
Mathew M. Braidech

The scope of the activities of this new division of research will include problems connected with the fire and related hazards of industry and commerce, materials of construction and their methods of use, and protective methods in safeguarding life and property.

Operating as a part of the Board's Engineering Dept., the research division will be under the general supervision of the Committee on Fire Prevention and Engineering Standards, and under the personal direction of W. E. Mallalieu, Gen. Mgr., and George W. Booth, Ch. Engr.

Prof. Braidech, in his nine years at Case has had much experience in the various aspects of water supplies, industrial hygiene, and explosion hazards. In his new position Mr. Braidech will be located in the New York office of the Board.

Novel Distributing Wall at Norfolk Filter Plant



The accompanying picture is a progress view of the Stewart Adjustable Venturi Throat Distributing Wall and the Stuart Walking Beam Flocculators, under construction in the coagulating basins of the 21 M.G.D. Moore's Bridge Filter Plant of Norfolk, Va.

The inset shows the unique adjustable flow distributing wall from above. The piers for the flocculator mechanism, which will agitate the coagulated water vertically, appear between the rapid mix chambers and the stilling and distributing wall. The rods across the top adjust the degree of opening through the Venturi shaped vanes, with a single lever setting at the end of the wall. There are two sets of flocculators and two distributing walls being installed in the two parallel coagulating basins, as a method designed to raise the capacity of the plant without basin enlargement.

An article by R. W. Fitzgerald, Sup't. of Water at Norfolk, describing this unique installation and results attained, is to appear in *Water Works and Sewage* after the installation is in service.

The Editor's Comments

"Just What I've Always Said!"

Not long since, I heard two superintendents discussing the matter of water rate bases. Naturally the question of the method of establishing a minimum charge and allowing a given quantity of water for this minimum charge *vs.* the method of making a service charge and billing for every gallon of water passing through the meter, came in for discussion.

This conversation brought to mind another which I had recently experienced. During one of the New England Water Works Assn's monthly meetings I heard a familiar voice saying "It's just what I've always said!" Turning around it proved to be Roger Esty, Sup't at Danvers, Mass., developing proof of a long held contention. His well taken position is that to practice the minimum charge method of providing water service, which method involves an allowance of a given quantity of water for the minimum charge before the *true* metered use rate becomes operative, is not sound practice, nor is it an equitable method of charging individual customers for water service. His very appealing argument is that water metering has the dual function of insuring a measure of water conservation practice by the consumer, who would otherwise permit water waste through leaking fixtures or careless water use; and, collection for water service on the equitable basis of actual water used by the customer.

The unfair practice in the minimum charge method is found in the fact that the customer who may use half the quantity of water that his neighbor may use (or waste) is paying just as much as this wasteful or indifferent townsman. Putting it another way, the careful customer may be paying twice as much per gallon of water metered to him as his wasteful or indifferent neighbor pays. The unwise practice in the minimum charge method is that which permits the consumer to waste water with little regard, and offers him no incentive to have leakage on his premise corrected. The latter type of customer soon learns that he actually is money ahead by *not* having had leakage corrected. This is so, because the plumber must be paid and the customer saves nothing, since the water bill is not reduced thereby.

Evidence which can be supported by exhibits is the more valuable in any argument. So, as "Exhibit A" Supt. Esty introduced a letter and a water bill which had recently been received from a former young lady, employee in the Danvers Water Dep't. The young lady, now married and living in a Florida city wrote her former boss as follows: "I am enclosing our water bill for last month. These bills that we get every month have proved to me over and over *what you have always said* about minimum rates. You will see that the minimum here is $2.00 and allows us 7000 gallons for the month. The meter reading shows only 3000 gallons, so we don't even try to save water—just let the faucets drip. At least Bill does, but I've naturally heard so much about saving water that I can't."

As Roger Esty pointed out, here was a bill showing a meter reading from which even the "dumb" could figure out that they were not using up their water allowance ("ration" is perhaps the timely expression) by 4000 gals. for the month. So why be concerned by the leaks; why not let the hose run all night; why conserve water that must be paid for whether used or not? Perhaps fortunate for the management of such water utilities employing the minimum charge method, the conscientious and the penurious customers fail to comprehend that on a pro-rata basis they are paying far in excess of a fair share of the costs of providing water service to the community. However, that is exactly what many customers are doing in the final analysis of the situation, and the old argument that universal metering insures equitable payment for water supply service has something of a hollow ring when the minimum charge method is employed.

One can't help but agree with the Esty dictum that there is but one truly fair and equitable method of providing any paying for water service—namely, an equitable service charge plus a meter rate which requires payment for the exact quantity of water supplied and only that. The question is,—Why meter customers, and go through the motions of billing on a metered use basis, when in truth this method of charging amounts to little more than the flat-rate method, regardless of what the method may be termed.

Hagerstown Sets a Pattern

For some time it has been our intention to make a plea to municipalities for considertaion of what we believe should be a nation-wide plan in the nature of post-war projects. We refer to reforestation, not alone as a measure for benefiting watersheds, but even beyond this.

As an unemployment relief measure there can hardly be conceived a measure which more genuinely and universally deserves consideration than that or reforestation. The work can be started quickly, moderated to suit circumstances, or stopped abruptly. The initial investment is negligible, the ultimate benefit large and permanent. Should Federal assistance be made available to stimulate post-war employment there could be no more universally deserving expenditure of Federal funds than for the purpose of re-establishing forests the nation over.

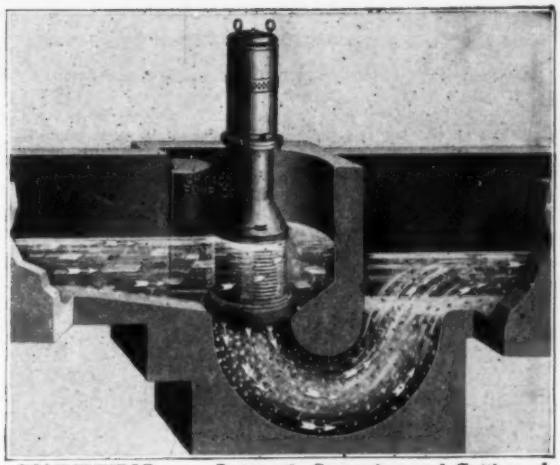
We are happy to have secured from W. R. LaDue his story, based on 23 years of experience in beneficial reforestation on Akron's watersheds. This we feature in this issue. We also hope to be able to present the experiences of others in reforestation.

An additional aspect of the merits of reforestation has just recently come into the spotlight. Hagerstown, Md., wishing to establish a war-memorial to its citizens who fought and died in World War II, has concluded that no memorial could be more fitting, more permanent, than the establishment of a *living* memorial in the form of a "War Memorial Forest." In this the industries of Hagerstown and the people of Washington County concurred. The result is that a Memorial Forest has been planned and the first trees have already been planted by the boys and girls of the county's 4-H clubs.

Appropriately enough, the Memorial Forest is being established on Hagerstown's Warner Hollow watershed. In planting the first tree Mayor Richard Sweeney said that it was "Hagerstown's hope that there might be many more similar memorial reforestation projects throughout the nation." In this hope, Mayor Sweeney, *Waterworks and Sewerage* is happy to repeat and endorse your very worthy suggestion.

L. H. Enslow

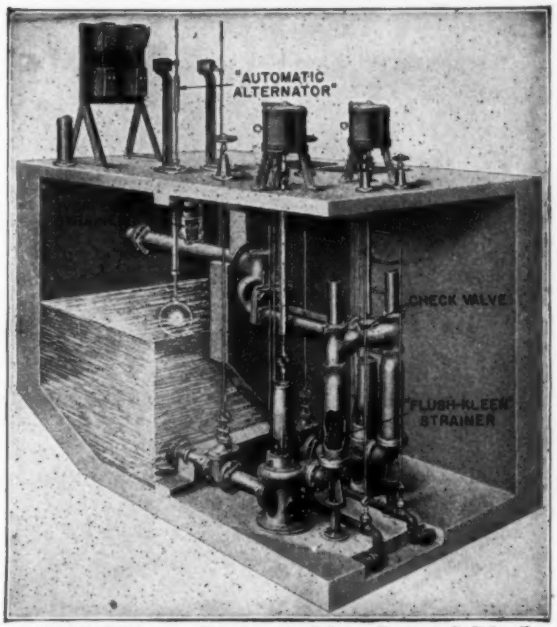
SEWAGE HANDLING PROBLEMS SOLVED



COMMINUTOR . . . Automatic Screening and Cutting of All Coarse Sewage Matter.

SOLVED

SCREENING LABOR AND NUISANCE is eliminated with Comminutors by sub-surface, automatic screening and cutting of all coarse material in the sewage. No screenings to handle, no burial, no incineration. The comminuted solids settle out in the primary tank and are disposed of with the primary sludge. Comminutors protect mechanical equipment against binding, pipes against clogging, and the operator against infection from handling screenings. Ask for Bulletin 185.



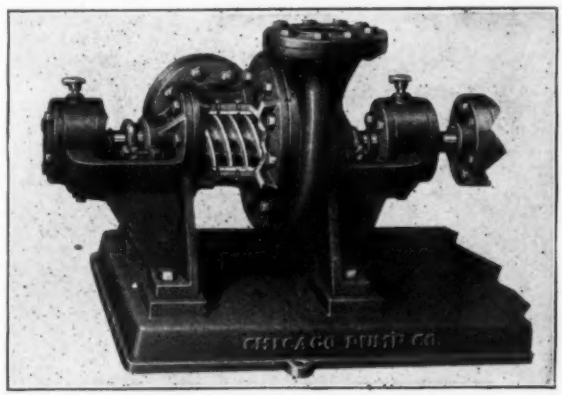
FLUSH-KLEEN . . . Rags and Other Coarse Solids Do Not Pass Through Impeller.

SOLVED

PUMP CLOGGING is never experienced with "Flush-Kleens," the most reliable sewage pumps made. Solids are automatically screened from impellers and flushed to sewer. The pumps require no maintenance, except periodic lubrication. Ask for Bulletin 122.

SOLVED

PRIMARY SLUDGE PUMPING as easy as clear water pumping with the "Scru-Pellers," centrifugal pumps with screw feeds. Nine cutting edges provide continuous multiple shearing actions all the way through the pumps. Ask for Bulletin 190.



SCRU-PELLER . . . Centrifugal Pump With Cutting Screw Feed.

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Flush Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs, Water Seal Pumping Units, Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

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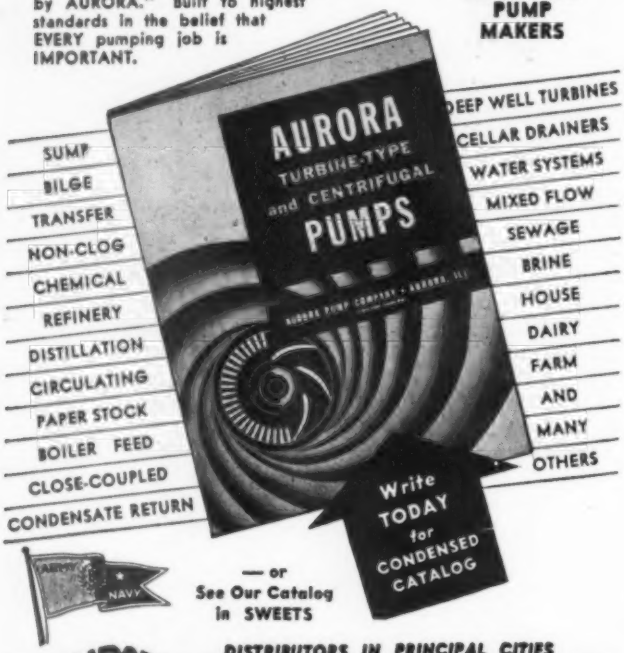

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No Caulking Materials

No Gaskets. No Bell Holes to Dig.

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STREET .....

CITY .....

MEETINGS SCHEDULED

IMPORTANT

Meetings, conferences, short schools, which will require hotel rooms or sleeping car accommodations for no more than 50 persons are considered as local or sectional meetings, and a permit from the Federal War Committee on Conventions to hold such meetings is not required. Therefore many conferences and short schools can be held without filing an application.

Indiana Section, AWWA

Sec'y, C. H. Beckert, Room 402, State Library, Indianapolis
June 12—Muscatatuck State Park, No. Vernon
June 13—Water Works Plant, Evansville
June 14—Shakamak State Park, Jasonville
June 15—Country Club, Crawfordsville
June 19—Sportsman Inn, Monticello
June 20—Country Club, LaPorte
June 21—Country Club, Columbia City
June 22—City Park, Anderson

Aug. 8—NORTHEAST HARBOR, ME.
Maine Water Utilities Association. Sec'y, Earle A. Tarr, Supt. Water District, Winthrop, Me. (Next meeting Oct. 10, at Bath, Me.)

Federation of Sewage Works Ass'ns
(Annual Conference Indefinitely Postponed)

The Federation's Annual Conference, planned for Toronto in September, has been postponed for an indefinite period. However, the Federation's Board of Control will hold its annual business meeting on Oct. 17 and 18, at some centrally located point, to be announced.

*Sept. 19-20—GRAND RAPIDS, MICH.
Michigan Section A.W.W.A. Sec'y-Treas., M. H. Gerardy, Dept. of Water, Water Board Bldg., Detroit 26, Mich.

*Sept. 14—PITTSBURGH, PA. (Roosevelt Hotel)
Western Pennsylvania Section A.W.W.A. Sec'y-Treas., E. P. Johnson, 418 Flannery Bldg., Pittsburgh 13, Pa.
(Joint Meeting with)
Pennsylvania Water Works Operators Association. Sec'y, I. M. Glace, 22 South 22nd Street, Harrisburg, Pa.

*Oct. 15-17—(Meeting place announced later)
Southwest Section A.W.W.A. Sec'y-Treas., L. A. Jackson, Gen'l Mgr., Water Dept., Little Rock, Ark.

*Oct. 23—LOS ANGELES, CALIF.
Oct. 25—SAN FRANCISCO, CALIF.
California Section A.W.W.A. Sec'y.-Treas., B. I. Burnson, Box 720 Oakland 4, Calif.

*Oct. 30-31—MILWAUKEE, WIS.
Wisconsin Section A.W.W.A. Sec'y-Treas., Leon A. Smith, Supt. Water Works, City Hall, Madison, Wis.

*Nov. 5-7—CHARLOTTE, N. C. (Hotel Charlotte)
North Carolina Section A.W.W.A. Sec'y, D. M. Williams, Supt. of Water & Sewerage, Durham, N. C.

*Nov. 8-9—ROANOKE, VA.
Virginia Section A.W.W.A. Sec'y-Treas., W. H. Shewbridge, State Health Dept., 1506 Greycourt Ave., Richmond 22, Va.

*Nov. 8-10—ATLANTIC CITY, N. J. (Hotel Madison)
New Jersey Section A.W.W.A. (Fall Meeting.) Sec'y, C. B. Tygert, Box 178, Newark, N. J.
(Joint Meeting with)
South Jersey Association of Water Superintendents. Secretary, Walter Spencer, 2707 Bethel Ave., Merchantville, N. J.

*Nov. 13-15—MILWAUKEE, WIS.
Wisconsin Section A.W.W.A. Sec'y-Treas., Leon A. Smith, Supt. Water Works, City Hall, Madison 5, Wis.

*Nov. 15-17—(Meeting place announced later)
Florida Section A.W.W.A. Sec'y-Treas., Prof. A. P. Black, University of Florida, Gainesville, Fla.

*ED. NOTE: A.W.W.A. Section Meetings here listed for fall dates are scheduled contingent upon the attitude of the War Committee on Conventions later in the year.

AMBURSEN DAMS

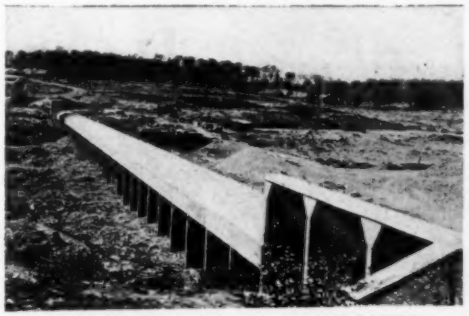
SINCE the construction of the first AMBURSEN TYPE DAM at Theresa, New York, in 1903, about 400 of these structures have been built. Difficult foundation problems have been successfully solved, about 175 of the total number of AMBURSEN DAMS having been constructed on soft or porous foundations that prohibited the construction of any other permanent type of dam.

AMBURSEN DAMS are scattered all over the world, on foundations varying from ledge rock to sand and silt, and under climatic conditions varying from the tropical heat of the Malay Peninsula to the continuous cold beyond the Arctic Circle in Scandinavia. Eighteen have been constructed for the United States Government and over sixty for American municipalities. Utilized repeatedly by a multitude of industrial and public utility owners, the AMBURSEN TYPE DAM offers to the engineer safety, permanence and economy.

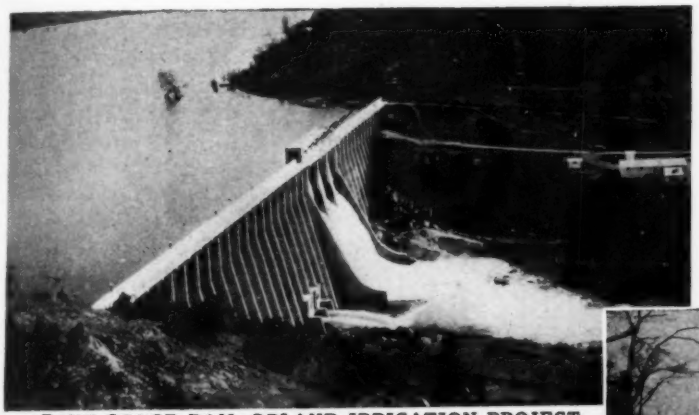
The partial height method of constructing AMBURSEN DAMS effects low initial cost and minimum carrying charges for hydroelectric and water supply developments, permitting economical future increase in height when required.

Various AMBURSEN TYPE DAMS have been successfully constructed with power houses or filter plants enclosed within the dam structure itself, at a substantial saving in first cost and in operating expense.

FLINT DAM, KEARSLEY CREEK, MICHIGAN, 1928
Municipal water supply. Clay foundation



WOODLAND DAM, ST. CROIX RIVER, MAINE-CANADA BOUNDARY, 1912
St. Croix Paper Company; storage. Rock foundation



STONY GORGE DAM, ORLAND IRRIGATION PROJECT, CALIFORNIA, 1928
U. S. Bureau of Reclamation. Built across a geological fault

REMMEL DAM, OUACHITA RIVER, ARKANSAS, 1924
Electric Bond & Share Company; hydroelectric plant. Rock foundation

41 YEARS OF SUCCESSFUL USE

Highest safety factor of any type of dam.

Subject to rigid scientific analysis throughout.

Maximum resistance to sliding and over-turning.

Uplift pressure eliminated.

Foundation loading uniform and controllable.

Positive provision for expansion and contraction.

Permanence unaffected by climatic conditions.

Economically adaptable to any foundation.

Send for Literature, Cost Data, Photos.

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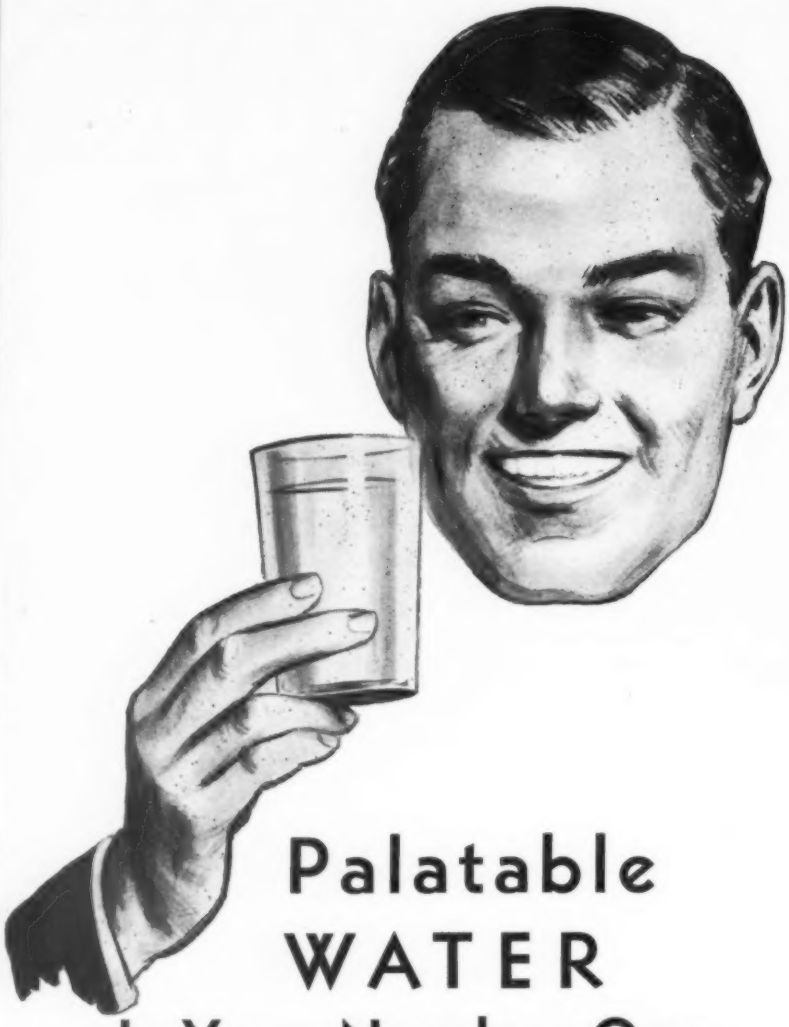

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Here and There with Doc Symons

Last March, I wrote that so far as I knew there were less than a half dozen girls in sewage work in this country, whereupon Albert Tawney, Assoc. San. Engr. of Ft. Meade, Md. wrote this letter to the column: "Thought you'd like to know that we have here at Ft. Meade, one Mrs. Flo H. Ward, who, as Asst. San. Engr. is in charge of the operation of a modern Bio-Filtration sewage treatment plant, and has the supervision of sixteen (16) male workers (seven of whom are prisoners of war).

"Mrs. Ward, a graduate of the Univ. of Georgia, was an operator at the Ft. Eustis, Va. disposal plant before coming to Ft. Meade. This lady has also completed a six months' course in all phases of water works operation; she is very efficient and gets along fine with male employees of all departments. She is also a member of the Md.-Del. Water and Sewage Assn."—I hope she's a subscriber to W.W.&S., too, Al.

* * *

To return once again to the subject of modernizing our system of measurements, I had hoped to bring you some of the enlightened and enlightening comments of a group of

SAVE *with* TENNESSEE CORPORATION Ferri-Floc FERRIC SULPHATE

Write today for actual case histories of plants now using the ideal ferric coagulant.

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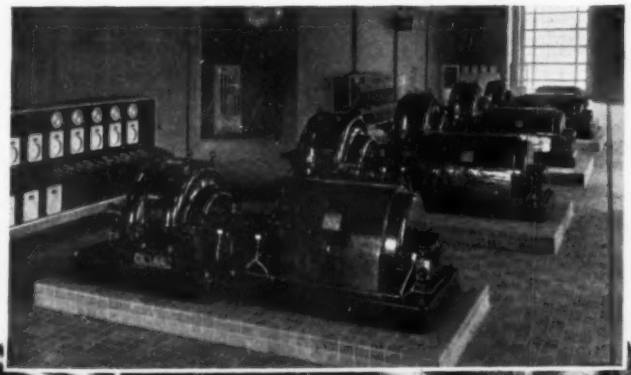
Atlanta, Georgia Lockland, Ohio

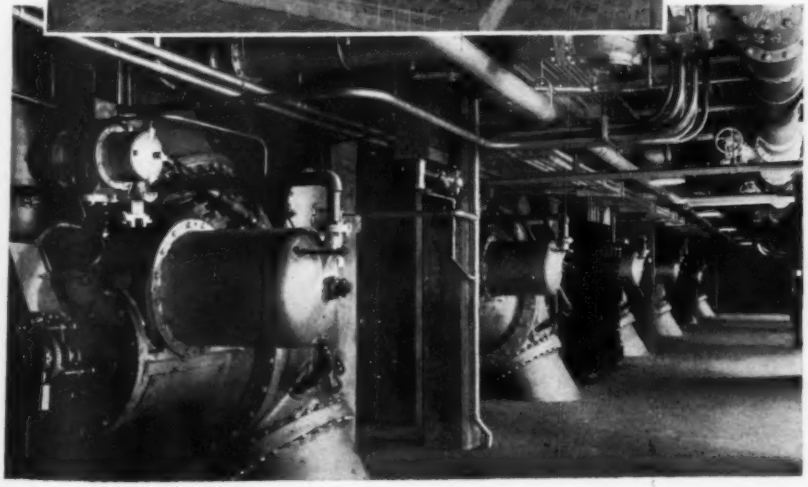
Cleveland's Modern Sewage Disposal Plant

Is Equipped with

ROTOVALVES

by S. MORGAN SMITH COMPANY for Compressor Check Service





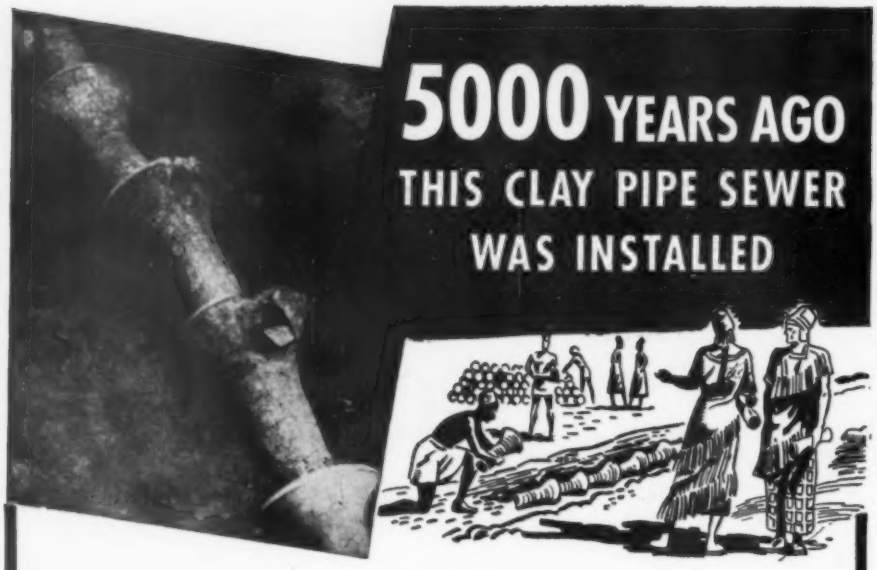
PROTECTING the motor driven centrifugal blowers, shown at the left, are 3—36″ and 2—30″ Air Check Rotovalves, at the EASTERLY SEWAGE WORKS pictured above, which are operated by pneumatic cylinders deriving air from the line at 7½ pounds pressure.

The selection of Rotovalves was made after searching analysis, and constitutes a tribute to their performance and dependability!

If in need of information covering similar operating problems and applications write us for details.

S. MORGAN
SMITH
COMPANY

YORK
PA.



5000 YEARS AGO THIS CLAY PIPE SEWER WAS INSTALLED

YES, 5,000 years ago architects, engineers and contractors knew about clay pipe and used it. This pipe, lacking all the improvements of modern vitrified clay, but the same in principle, was found in ancient Babylon.

You may not reasonably expect a sanitary sewer, highway, airport, railroad, public building, factory or home to last 5,000 years. But the economy of using Clay Pipe for any kind of sewerage or drainage is something that you *can* expect, because properly installed Clay Pipe will insure future generations the use of the job you do today.

The reason for the long life of *Vitrified Clay Pipe* is the fact that it is chemical-proof and abrasion-proof. Clay Pipe is impervious to acids, alkalies, industrial wastes, gases and the grinding abrasion of moving sand and gravel. It will not corrode, decompose or crumble. *Clay Pipe* is strong, durable, economical and easy to use. Consider final costs as well as first costs, and you will find this true: "IT WILL PAY TO USE CLAY."

WRITE FOR INFORMATION

Through its technical engineering staffs, the Clay Pipe Industry carries on constant research to improve products and to adapt them to current construction practices. For latest information or engineering literature, contact one of the four regional offices or write to:

NATIONAL CLAY PIPE MANUFACTURERS, INC.
111 W. Washington St., Chicago 2, Ill.

C-1244-19

SPECIFY CLAY PIPE

water works and sewage men, for whom I have the highest regard—and respect—same being members in that exclusive organization, $P_3B_3P_2$.

I find, however, that two of the members (one being Marsden Smith) had copyrighted their remarks, one had commented only on those copyrighted remarks, while Harry Krum, the Water Fixer of Allentown, and Alan Darby didn't even write on the subject. It is with deep regret, therefore, that I cannot devote this column to the subject, as planned.

On the other hand, Arthur Clark, the one, the only, the incomparable Mgr. of WSWMA, did not copyright his comments and I am pleased, therefore, to bring them to you, herewith—quote:

"In speaking of changing old things for new, you have apparently been so confused in consideration of weights and measures, the American-English, and metric systems, and with your endeavor to convert °F into °C and our good old fashioned twelve-month year into the unlucky number 13, that you have completely ignored one of the most important measurements—**Time.**

"Now if you really want to do something constructive I suggest you bring to your eager readers the following plan for out-daylighting daylight savings time.

"The first step is to stop in at your favorite watchmakers along about next Jan. 1, and have your watch adjusted to run one minute fast each day. You won't miss the minute but by June 21st you will be on a super-duper daylight savings and while the kitchen clock says 6 a.m. you'll be catching the 9 o'clock train to the city and by the time it's 9 a.m. in your kitchen you'll be out to lunch.

"The next step is to return to your jeweller on June 21 and have him readjust your watch to run a

TAPAX

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Manhole Cushion U. S. Pat. No. 2,050,050 offers you the simplest solution for noisy, rattling covers. Easy to install. Lasting — Economical.
Write for story of Tapax and Trial Offer.

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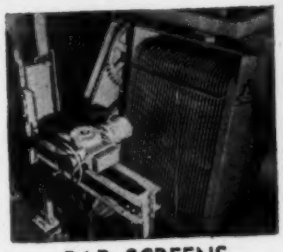
"KNOW-HOW" IN PURIFICATION

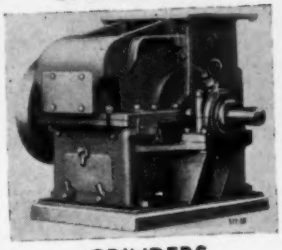
Water, Sewage and Industrial Wastes

Jeffrey Sanitary Engineers are specialists . . . can give you technical information on the proper equipment . . . complete plants or individual units.

In addition to units shown, Jeffrey makes Chemical Feeders, Flectrols (controlled flocculation) and equipment for bio-filtration plants as well as a general conveyor line of modern design.



BAR SCREENS



GRINDERS

GRIT COLLECTORS

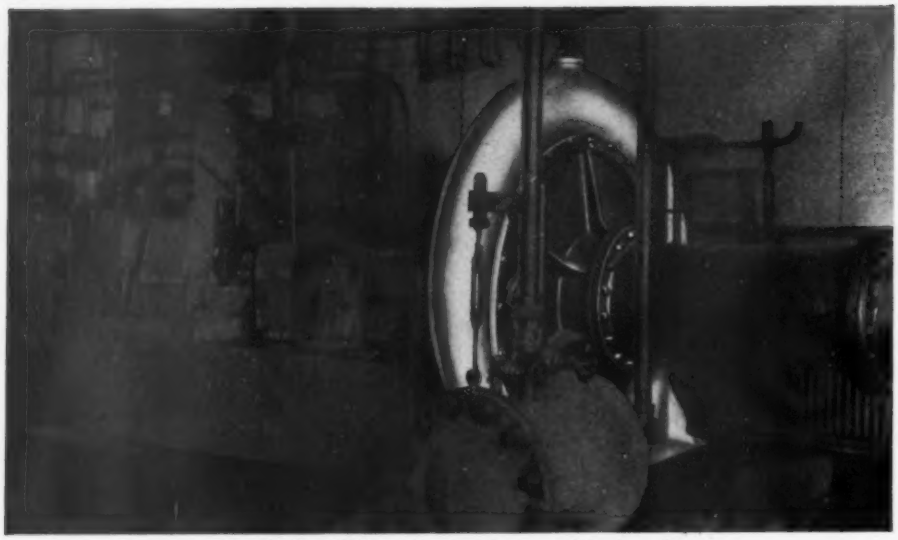
JIGRIT WASHERS

Primary and secondary sludge collectors in Bowery Bay Activated Sludge Plant, New York City

211-43

JEFFREY

ESTABLISHED 1877



Installation of Morris Sewage Pump and Engine, the No. 1 Pump, Metropolitan District, Quincy, Mass.

OVER 20 YEARS OF SERVICE

Without Repairs or Replacements

★ This sturdy Morris Pump, setting its stride back in 1923 at 10,000,000 gallons of sewage a day, is still operating. Morris engineers planned this measure of service over twenty years ago. Morris Pumps are engineered to take their load easily, smoothly, and without perceptible vibration. They are ruggedly built and precision-machined for efficient and enduring service.

★ This Morris 16-inch, side suction, wide-clearance-impeller sewage pump, directly driven by a 10" & 20" x 10" Morris Vertical Compound steam engine, was installed by the Starkweather Engineering Co. Presently, this pump will be taken off the line for the first time in 20 years, dismantled and inspected for wear. After repairs, this pump will again resume its function as the No. 1 Pump of the Quincy Station.

MORRIS SERVICE

The efficiency of this old pump compares very favorably with the high efficiencies attained today. It is, therefore, a dollars-and-cents economy to repair rather than replace this long-service unit.

★

Here is another example of Morris Pump efficiency, performance and endurance; again demonstrating the achievements of eighty-one years of pump engineering.

Write for Sewage Pump Bulletin No. 160

MORRIS MACHINE WORKS
Baldwinsville, N. Y.
Branch Offices in Principal Cities

MORRIS CENTRIFUGAL PUMPS

minute slow each day and along about the end of December you'll be back on standard time and ready to start all over again. This is known as the 'Clark Effect.'" Unquote.

Mr. Clark is a modest man, but deserves recognition for this fundamental contribution to science. This column will offer one package of cigarettes to the best explanation of the "Clark Effect."

* * *

Last January the boys in NYSSWA made me eligible to receive a past-president's key next Jan. and in discharging the prexy's duties I'm making the section meetings. It was late in April in Kenmore as Chan Samson's guest that I became interested in garbage incineration, a week later in Lyons I had a lot of fun in the fire house reminiscing with several of Bill Denise's gang from Rochester about some lectures I gave way back when, and less than a month ago at the L. I. Sect. meeting (Tallman's Island—a show place both as to looks and operation) I achieved an ambition of long standing—to speak on the same program with A. M. Rawn of Los Angeles Co.—I was so excited, I forgot half of what I was supposed to say.

* * *

Before I forget it, ladies, here's a household hint for this month. If you are troubled with odors in your refrigerator, as who isn't from certain foods, and if you can't make your husband bring home some activated carbon from the water plant, then cut a lemon in half and put one-half on the top shelf and the other half on the bottom shelf. Use a new lemon each week, but don't try to salvage the juice in the old one for a lemonade.

* * *

SAVE MONEY USE ACTIVATED ALUM and BLACKALUM

STUART-BRUMLEY CORP.
516 North Charles St.
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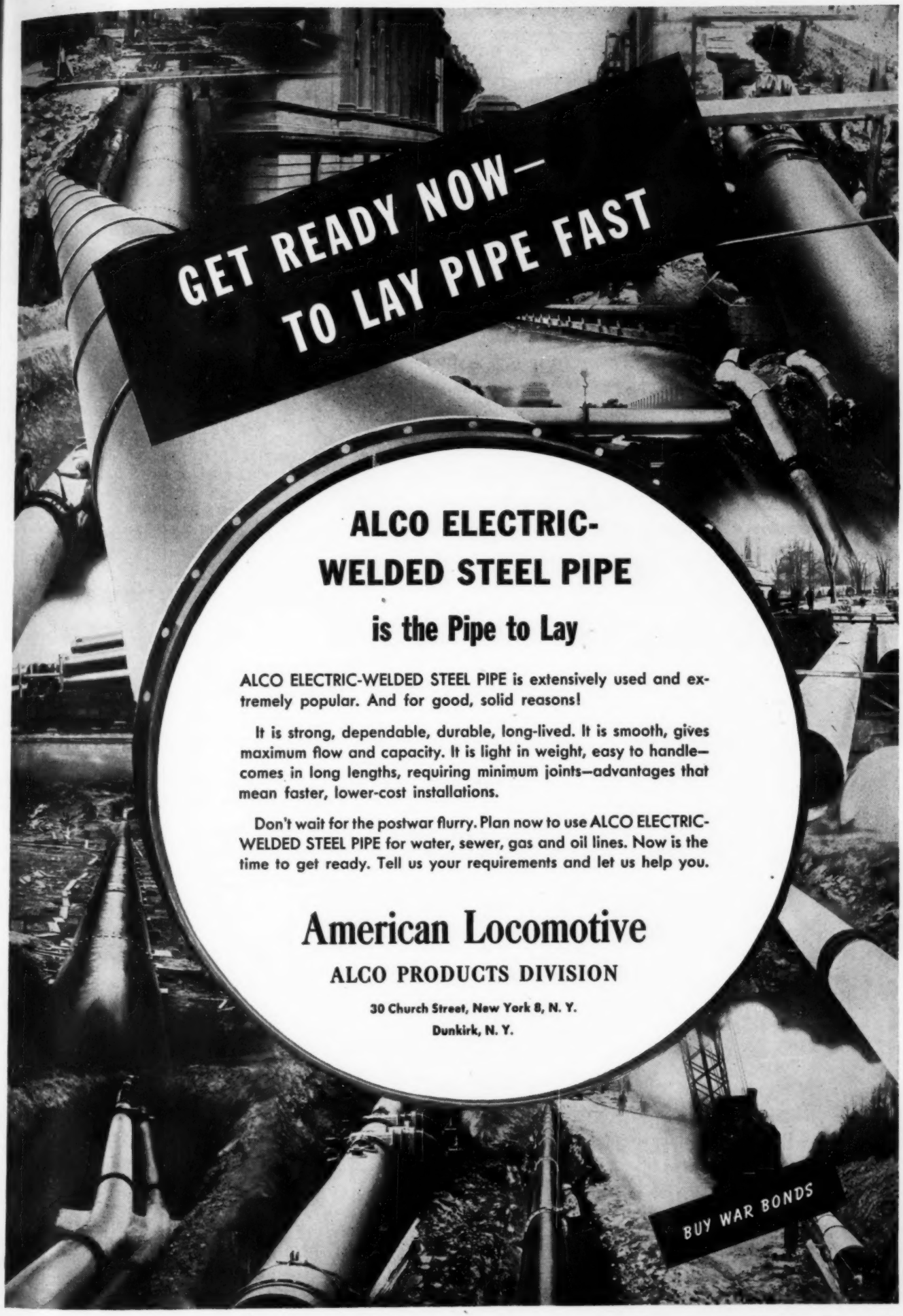
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WELDED STEEL PIPE
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ALCO ELECTRIC-WELDED STEEL PIPE is extensively used and extremely popular. And for good, solid reasons!
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Don't wait for the postwar flurry. Plan now to use ALCO ELECTRIC-WELDED STEEL PIPE for water, sewer, gas and oil lines. Now is the time to get ready. Tell us your requirements and let us help you.
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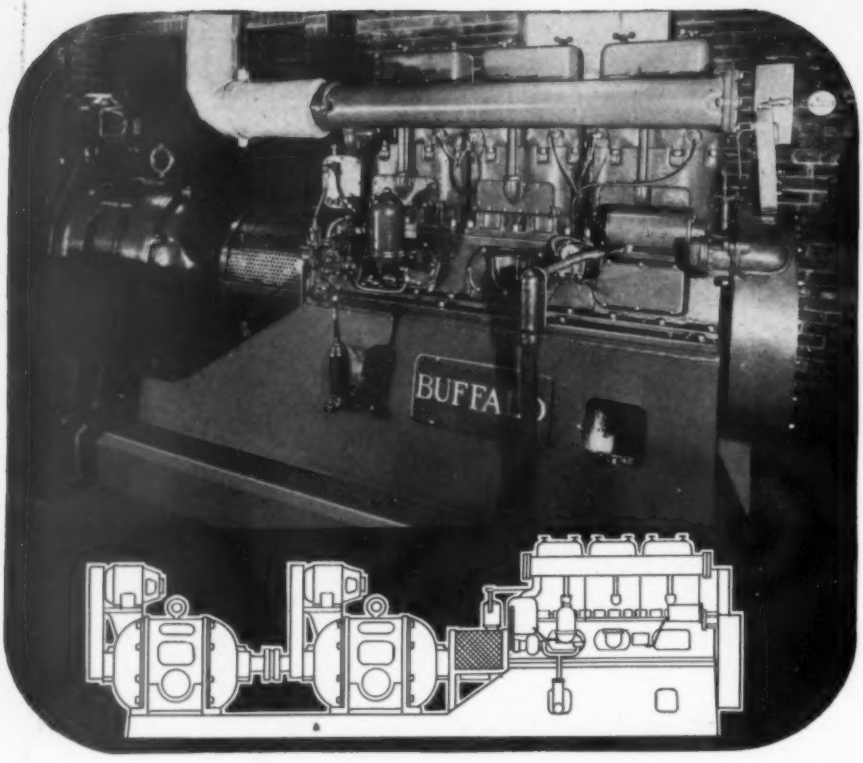

RAB-6 BUFFALO Gas Engine at Bay Shore Gas Company, Bay Shore, L.I. 50 KW—250-Volt, 3-Phase, 60-Cycle and 25 KW—125-Volt, 1-Phase, 60-Cycle.

FULL RATED POWER

SOUND engineering calculation checked by years of experience is the best assurance of successful engineering works. Power installations that include BUFFALO ENGINES have always the benefit of over forty years of building engines and observing the results of thousands of important applications.

This knowledge of our customers' needs is reflected in the specifications of BUFFALO ENGINES and in the variety of engine models we build for different types of duty.

If you are planning works that call for stand-by power equipment (or even if you are only interested in keeping your file up to date), you are invited to write for specification sheets and any other information you desire.

We are planning for publication a series of papers on different works that require stand-by power. Please tell us the type of installation in which you are interested.

BUFFALO GASOLENE MOTOR COMPANY

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BUFFALO ENGINES

ASSURANCE of PROTECTION

BUFFALO ENGINES — 100 H. P. THROUGH 750 H. P.— IN GENERATOR AND PUMPING SETS FOR WATER WORKS — AIRPORTS — COMMUNICATIONS — FLOOD CONTROL — HOSPITALS — INSTITUTIONS — MINES — MOVABLE BRIDGES — THEATRES — SEWAGE PLANTS.

George A. Rhame of Columbia, S. C. wrote that a sewage works association was being formed in that state and that the first meeting was scheduled for April 9th. I haven't heard yet how the meeting turned out or who was elected president or how many members— "Why doesn't somebody tell me these things?"

* * *

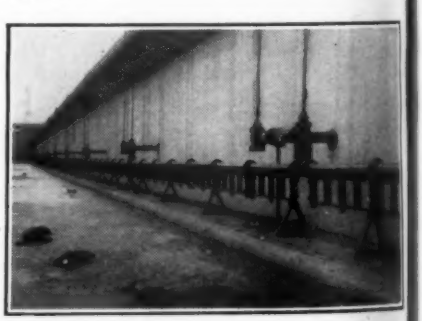
Famous last lines: This is the 1945 Ref. & Data issue. It's worth saving—*and* you should hang on to the 1944 and 1943 June issues also if you want a good reference library. You'll find the index to all three at the back of this issue.

MANUFACTURERS' and EQUIPMENT News

P.F.T. Vertical Aeration Plate Holder

The P.F.T. Combination Integral Air Main and Vertical Aeration Plate Holder is not exactly new, but its development is recent enough that only now has there been a news release on it.

This combination air main and vertical plate holder (Piatt's Patent) is manufactured by the Pacific Flush Tank Co. of Chicago, which has a typical installation at Camp Butner, N. C.



The unit has a laying length of 4 ft. 6 in. and holds eight standard 12-in. square diffuser plates in two rows, one on each side, below the air main. A wedge block locking arrangement simplifies the installation and removal of plates for cleaning or replacement.

THE O.D.T. DOESN'T BAN FRIENDSHIP

SEVENTY-SIX YEARS
HAYS
DEPENDABLE SERVICE

WE'RE sorry that Uncle Sam finds it necessary, through his Office of Defense Transportation, to say that we can't meet in St. Louis, or elsewhere, this year. We're not questioning his judgement, and it's a small sacrifice to make if it's going to help in the smallest measure to hasten the day of permanent peace.

So, we'll be missing you and thinking about you. For 76 years we have considered that *customer* and *friend* were synonyms. We have looked forward from year to year to the chance to greet you, at the A. W. W. A. conventions.

This year our greetings must be extended in this printed form. Don't think they are less hearty for that . . . you have been patient and considerate, because you knew we were striving to do two jobs, take care of your needs, and supply Uncle Sam. We'll continue to do our best.

So again, greetings and good luck until our next convention, we hope in 1946.

BE SURE TO REPLACE WITH ANOTHER HAYS STOP

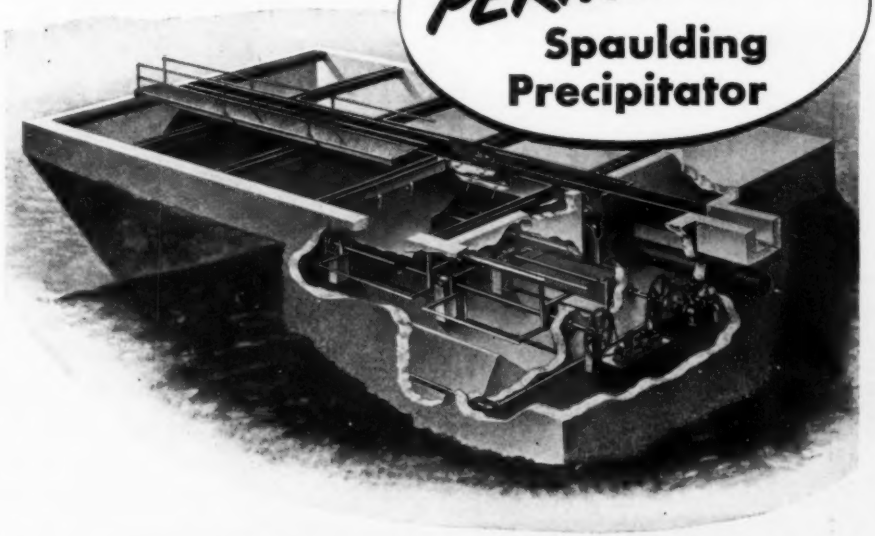
SEVENTY-SIX YEARS HAYS DEPENDABLE SERVICE
COPPER BRASS LEAD IRON
WATER WORKS PRODUCTS
HAYS MANUFACTURING CO., ERIE, PA.

Back the 7th War Loan Buy More Bonds

New-design equipment for removing water hardness . . .

Cuts detention time, saves chemicals, takes only ½ the space of former methods

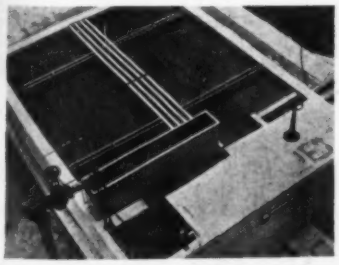
PERMUTIT
Spaulding Precipitator



It removes water hardness, dirt and color by the sludge blanket process, cutting detention time and saving chemicals.. It requires only half the space of former methods. No wonder engineers, in blueprinting their water improvement plans, specify the Permutit* Spaulding Precipitator.

If YOUR postwar program includes water conditioning—and it should—write for details of this modern, efficient equipment. Address The Permutit Co., Dept. G1, 330 West 42nd Street, New York 18, N. Y., or Permutit Co. of Canada, Ltd., Montreal.

*Trademark Reg. U. S. Pat. Off.



PERMUTIT SPAULDING PRECIPITATOR removes water hardness, dirt and color by the sludge blanket process. This new-design equipment cuts detention time, saves chemicals, takes only half the space of former methods. Present installations handle up to 120,000,000 gallons daily.

PERMUTIT

WATER CONDITIONING HEADQUARTERS

how to give water a BATH!

Even sparkling, clean-looking water needs a thorough "going over"... for like a germ-infested jungle stream, it can be the carrier of deadly water-borne germs.... It can tumble forth the wastes and impurities of industrial plants.

To make water **safe,** both on home and battle fronts, engineers rely on versatile Solvay Liquid Chlorine. This liquid effectively gives water a **bath** – "washing" out impurities, foul tastes and odors.

Today Solvay Liquid Chlorine is serving on two fronts. Tomorrow it will serve municipalities and industry with newly discovered uses.

SOLVAY
LIQUID
CHLORINE

SOLVAY SALES CORPORATION

Alkalies and Chemical Products Manufactured by The Solvay Process Company

40 Rector Street **New York 6, N. Y.**

Another War Hero Joins Neptune's Sales Staff

The Neptune Meter Company announces the appointment to the sales staff of their Canadian subsidiary, Neptune Meters, Ltd., of Mr. W. J. (Bill) Waddell, formerly Captain Waddell of the Royal Canadian Artillery. Mr. Waddell is the son of W. H. Waddell, City Engineer of Owens Sound, Ontario, presently Chairman of the Canadian Section of AWWA. Before entering the service, he was with the Surveys Branch of the Ontario Department of Highways.

"Bill" Waddell
(Former Captain, Royal Canadian Artillery)

Having served in the Royal Canadian Artillery for five years, four of which he spent overseas in Italy and France, young Captain Waddell won the coveted Military Cross for his exploits at Falaise. There, with only a few men, he effected the capture of several German tanks of the largest type. He was later captured by the Germans, after having been clipped by a sniper's bullet which very nearly cost him his life, but was soon released when the Germans found themselves completely surrounded by the Canadian troops.

H. G. Turner Dies Suddenly

H. G. Turner, who for many years held a professorship at State College, Pa., died suddenly in Erie, Pa., on May 18th. Prof. Turner was best known in the water works field as Research and Development Engineer of the Anthracite Equipment Corp., and as the man who literally put "Anthrafilt" filter media on the water works map all over the country. Homer G. Turner had been connected with the Anthracite Equipment Corp. since 1936 and his work on Anthrafilt has received wide attention. Mr. Turner's latest article on the subject is reprinted in the Reference and Data Section of this issue.

H. G. Turner

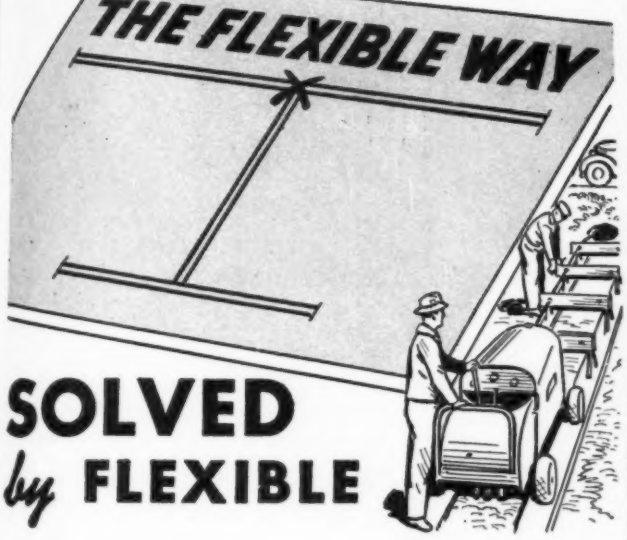
ANTHRAFILT
A Filter Medium For All Purposes

ANTHRACITE EQUIPMENT CORP.
101 Park Ave. New York

H. G. Turner Research Engineer
STATE COLLEGE, PA.

Other advantages of the air main-plate holder are uniform and effective air distribution throughout the length of the tank; no settlement of solids into plate pores and consequent blinding because the plates are above the floor and vertical; elimination of air main condensation; an automatic increase or decrease in the effective area of the plate as air flow increases or decreases; and almost immediate full recovery of uniform air distribution after air shutdown.

A PROBLEM... IN MATHEMATICS FOR THE *Water Dept.*



SOLVED *by* FLEXIBLE

Flexible pipe cleaning service means more than low cost cleaning — it means faster, better jobs with fewer dig-ups and fewer patches in the street.

Flexible's specialized equipment and "know-how" can save money for your city. Call the nearest Flexible representative and get an estimate for cleaning all or part of your pipe line system.

HOW MUCH DOES A DIG-UP COST?

Figure the cost of digging, the cost of back filling, the cost of patching, the cost of detouring traffic, the cost of repaving the street — These are the costs of an unnecessary dig-up in the street.

FLEXIBLE UNDERGROUND PIPE-CLEANING CO.

615 Pickwick Bldg. Kansas City 6, Mo.
1624 Harmon Place Minneapolis 3, Minn.
P. O. Box 694 Gulfport, Miss.
41 Greenway St. Hamden, Conn.

9059 Venice Boulevard
Los Angeles 34, California

401 Broadway New York 13
2645 E. 75th St. Chicago 49
P.O. Box 694, Pittsburgh
P.O. Box 165, Atlanta
147 Hillside Ter. Irvington, N. J.

Check List of Hooker Chlorine Uses

Water Sterilization
Clean Filter Beds
Algae Inhibition
Taste and Odor Control
Stabilization of Raw Sewage
Prevention of Filter Ponding
Sedimentation and Removal of Settleable Solids
Sludge Digestion
Reduction of BOD
Disinfection of Effluent

Chlorine does many jobs in the water works and sewerage fields some of which are listed above. These operations involving the use of chlorine are made easier for you when you know that your chlorine supply will always be of the same high quality. That's why Hooker Chlorine has maintained its popularity among chlorine users for so many years. They have learned through experience that from Hooker each new shipment whether in tank cars, ton containers or cylinders is consistently uniform and of exceptional purity.

Water Works and Sewerage officials too, are taking advantage of the help that Hooker's Technical Staff is always ready to give. Their specialized knowledge is available to help you make better use of chlorine.

This Hooker Chlorine Booklet, sent free when requested on your letterhead, contains valuable information about chlorine, its physical and chemical characteristics, hints on storage, precautions in handling and shipping. Write for your copy.

HOOKER ELECTROCHEMICAL COMPANY

Buffalo Ave. and Ward St.
NIAGARA FALLS, NEW YORK

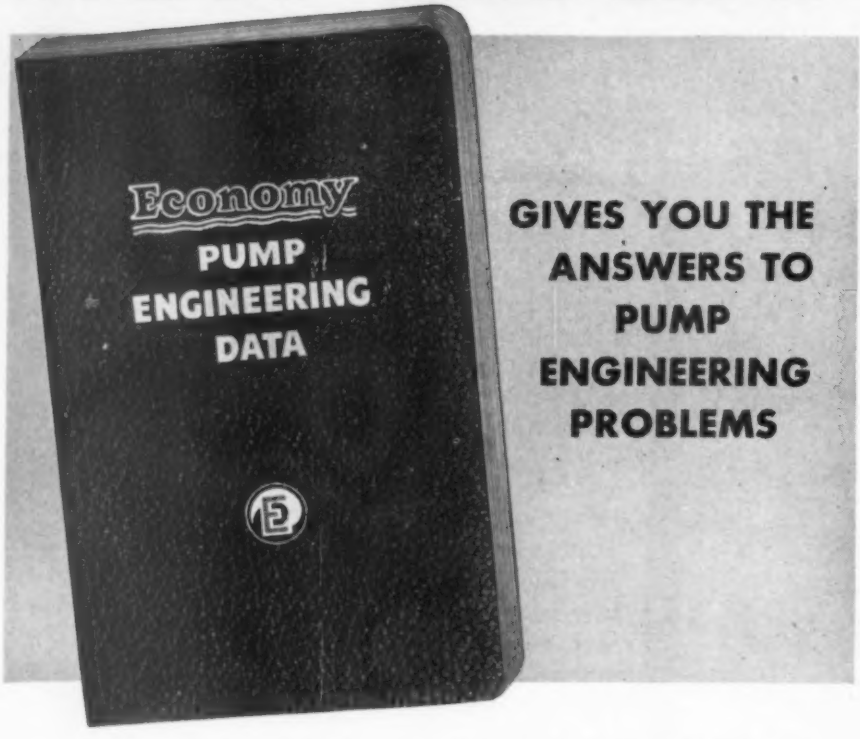
NEW YORK, N. Y. • WILMINGTON, CALIF.
TACOMA, WASH.

HOOKER CHEMICALS

Chlorine ***Bleaching Powder***
Caustic Soda ***Ferric Chloride***

5176

NOW READY



GIVES YOU THE ANSWERS TO PUMP ENGINEERING PROBLEMS

A timely contribution to the pump industry—416 pages of factual data just when vital postwar problems require authentic facts, sound experience and advanced engineering practice.

Here, under one cover, are hundreds of handy tables and diagrams you need every day. Revised, improved and new data governing the correct layout and installation of sewage, drainage, processing, heating systems, etc. Describes clearly and exactly the way to do the job right.

Indispensable to Executives, Engineers, Plant Managers, Maintenance Men, etc. Sent free in response to requests on business letterheads.

If your copy is delayed in reaching you, we're sorry, and ask your indulgence. The unprecedented demand temporarily exceeded the manpower for handling—but all requests received to date are being filled in rotation.

ECONOMY PUMPS, INC.
HAMILTON, OHIO • U. S. A.
FOR OVER THIRTY YEARS MAKING BETTER PUMPS DO MORE

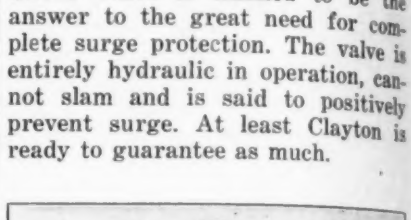
Electronic Signal Unit for Liquid Level Control

Here is a new electronically activated signal unit to indicate the level of aqueous liquids. It is the Faratron Electronic Control Unit, Model FSB, which, with two stainless steel electrodes and a 12x10x 5½-in. box housing a gong, lights and electronic unit, will warn when the tank is too full, or the liquid level dangerously low, or indicate when the liquid level is normal. Additional information may be obtained from the Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.

A Hydromatic Cushioned Check Valve

A New Development Offered for Even the Toughest Assignments

Clayton's new HYDROMATIC Check Valve is claimed to be the answer to the great need for complete surge protection. The valve is entirely hydraulic in operation, cannot slam and is said to positively prevent surge. At least Clayton is ready to guarantee as much.



The HYDROMATIC operates like a hydraulic door closer, because of the restraining action which is presented at the nozzle. In closing the final action is throttled, thus effectively preventing surge, shock and water hammer. The opening operation is similarly controlled. The initial action is throttled, so that pressures are equalized gradually.

Pressure to open and close the valve is directed through the SURGEMASTER Control and adjustment is provided, so that the speed of operation can be changed to meet various conditions of service imposed.

A descriptive bulletin of this new and widely adaptable valve should interest all water works men. For a copy write Clayton Manufacturing Co., Alhambra, Calif.

Sergeant Pulp & Chem. Co. Moves

The E. M. Sergeant Pulp and Chem. Co., manufacturers, importers, manufacturers' agents, and distributors since 1867, have moved from the Empire State Bldg. in New York to larger quarters at 7 Dey St., New York 7, N. Y.

Milford Rogers Builders' New Project Engineer

Milford E. Rogers, recently engineer and superintendent of the Wichita, Kan., Water System and later Acting Director of Service responsible for streets, sewage disposal, water supply and related functions for the City of Wichita, is now associated with Builders - Providence, Inc. (div. of Builders Iron Foundry), Providence, R. I.

Milford E. Rogers

In his new connection, Mr. Rogers, as "Project Engineer," will be concerned primarily with a combination of sales and service in connection with the company's specialty of over 50 years in the design and manufacture of flow metering, flow control and related equipment for water and sewage works.

Born in St. Louis, Mo., Mr. Rogers attended Washburn College and Kansas University, receiving a B.S. in C.E. from the latter institution. For several years he served the Santa Fe Railway Company in various capacities on design, maintenance and construction, later entering municipal work in 1937. Mr. Rogers will make his headquarters in Providence, R. I.

New Fairbanks-Morse Pump Div. Mgr.

Fairbanks, Morse & Co., Chicago, has announced the appointment of John S. King as Manager of the Company's Pump Division.

John S. King

Mr. King has had long experience with the company starting as a student in the Beloit Plant, where he assembled and tested pumping equipment and Diesel engines. In 1921 he was transferred to the Indianapolis Works of the company, building electric motors and generators, and since that time has been successively territorial representative on pumping equipment (1922), Manager of the Pump Department of that branch (1930), and Manager of the New Orleans Branch (1937), which position he held until his recent appointment a few weeks ago.

TRUSTWORTHY AS TIME

It's the consistent, day-in and day-out performance of Cook Deep Well Turbine Pumps that has justified their choice by men "Who Know." For, the ONE thing no price list shows—no catalog illustrates—is the *priceless experience* of specially trained craftsmen who take pride in assuring you the closer tolerances . . . finer finishes . . . higher efficiencies for which Cook products are famous. In deference to this genuine, painstaking craftsmanship we don't strive to build *all* the world's turbine pumps—*just the best ones.* Send today for Cook Catalog 360-A, and be convinced. Choice of oil or water lubricated.

In circle—view of Cook Flanged Coupling showing heavy welded and bolted joint. Left—section through Enclosed-Shaft Turbine. Note streamlined, mathematically precise passage through impellers and bowls to give maximum upward thrust to water column.

A. D. COOK, INC. DEEP WELL TURBINE DIVISION Lawrenceburg, Indiana

REX GRIT EQUIPMENT

FOR THE EFFICIENT SEPARATION OF SOLIDS

• There is a type of Rex Grit Collector available to meet any set of conditions. All types have incorporated in their design an exclusive recirculation feature that allows improperly separated materials, resulting from unbalanced conditions at low flows, to be returned to the channel during normal flows for resettling.

Grit Chambers, constructed according to standard Rex design principles, achieve highest efficiency through the use of properly proportioned channels of adequate liquid depth. Such chambers provide important control of velocity and distribution over a wide flow range.

TYPE ME—For Medium Flows in Shallow Channels—suitable for flows from 1,400 g.p.m. to 17,500 g.p.m. per single unit. V-shaped buckets, mounted on corrosion resistant Rex Z-Metal Chain Belt, travel along the tank bottom and convey the settled material toward the influent end of the channel, where they elevate the grit to suitable height above operating floor for discharge into cans. Stirring scrapers are interspersed between buckets to agitate settled solids. Buckets are equipped with perforated false bottoms to drain solids before discharge. Rex Grit Equipment also includes Type ME for medium flows in deep channels—Type MI for small flows in shallow channels and a Grit Washer for close separation of putrescible organics from inorganic material.

Blueprint Now!

Specially trained Rex sanitation equipment engineers can help you with your problems. For complete information, write Chain Belt Company, 1610 West Bruce Street, Milwaukee 4, Wisconsin.

REX **SANITATION EQUIPMENT**

Triturators • Bar Screens • Tow-Bro Sludge Removers • Slo-Mixers
Aero-Filters • Rapid Mixers • Grit and Sludge Collectors and Grit Washers

CHAIN BELT COMPANY OF MILWAUKEE

Member of the Water and Sewage Works Manufacturers Association, Inc.

Advancements at Crane

Crane Co., Chicago, has announced the appointment of Lucien W. Moore as Gen. Mgr. of Sales and Branch Houses, succeeding J. A. Dwyer, recently elected Vice. Pres. in Charge of Sales and Branch Houses. F. J. Wilkey, Dist. Mgr., Chicago, was appointed Manager of the Valve and Fitting Department, the position occupied by Mr. Moore until his recent assignment in France by the War Department.

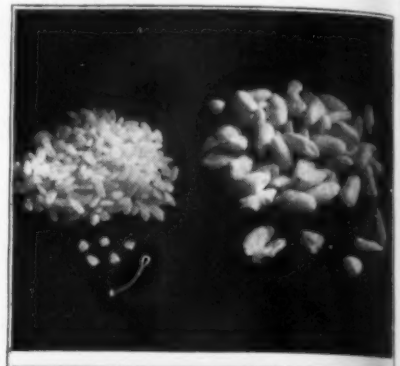
Mr. Moore was Mgr. of Sales of the Crane subsidiary in France until 1940. Since then he has been successively Manager of Pipe Sales and General Purchasing Agent, before his appointment as Manager of the Valve and Fitting Department. He will assume his new duties on completion of his present special mission for the government.

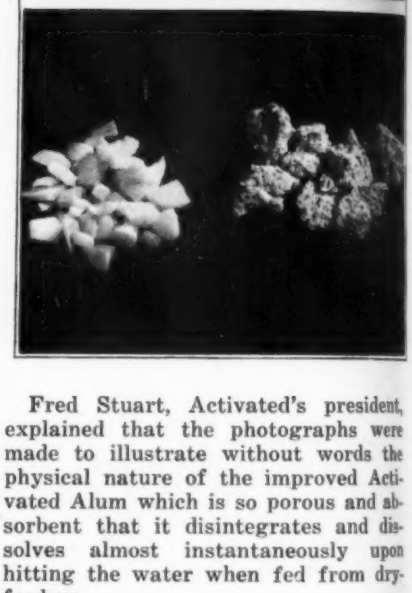
Mr. Wilkey started with the company in the Cleveland Branch in 1929 and was made Manager in 1939. He was promoted to District Manager at Cleveland in 1942 and transferred to the Chicago District in 1944.

"Sponge Alum"

(Our Name for Activated's Improved Alum)

Recently in the Baltimore office of Activated Alum the writer was intrigued by two brilliant photographs, remarkable for high-lights and detail. One was of a pile of polished rice contrasted to a pile of puffed (exploded) rice—one dense and non-absorbent, the other highly porous and absorbent. The second picture contrasted a pile of high purity crystallized filter-alum with a pile of highly porous "Activated" alum. These photographs are here reproduced.





Fred Stuart, Activated's president, explained that the photographs were made to illustrate without words the physical nature of the improved Activated Alum which is so porous and absorbent that it disintegrates and dissolves almost instantaneously upon hitting the water when fed from dry-feeders.

It has frequently been stated that the weakest part about dry chemical feeding is the smallness of the solution box which permits incompletely dissolved coagulant to enter the water with resulting efficiency loss if not economic loss also. With the highly porous and rapidly disintegrating "Activated Alum" the solution box deficiency is a factor of far less consequence—probably accounting for less of the porous alum being required in some instances.

For lack of a more descriptive or appropriate term we have called the improved product "Sponge Alum." If you wish more detailed information or a sample of this porous alum, write Activated Alum Corp., Curtis Bay, Baltimore, Md.

Food Machinery Buys Dayton-Dowd

To Become Branch of Peerless Pump Div.

The Dayton-Dowd Company of Quincy, Ill., one of the oldest and largest independent pump companies in the country, was recently purchased by Food Machinery Corp. and will become a branch of Peerless Pump division of Food Machinery Corp. Clarence M. Frazier will supervise all branches of the division with H. J. McKenzie, who has been Mr. Frazier's assistant, transferring to Quincy to control that branch.

Henry J. McKenzie

Clarence M. Frazier

Purchase of the company brings the number of affiliated plants to 15 under the control of Food Machinery Corp. The Peerless Pump division covers the United States with a sales organization and now has factories in Los Angeles, Quincy and Canton. It is now a manufacturer in both the horizontal centrifugal pump field as well as in the vertical turbine pump field.

Plans of Food Machinery call for continuation of the present plant in Quincy as Peerless Pump Division, Inc. It will be a branch of the Peerless Pump Division with headquarters in Los Angeles. Other branches and offices of Peerless include Fresno and Bakersfield, Calif., Canton, Ohio and Plainview, Texas.

All present lines now made by Dayton-Dowd will be continued, augmented, and expanded. Distribution will continue under the present sales representation.

Mr. William C. Dowd, vice pres. of Dayton-Dowd, will continue as executive in charge of engineering of the Quincy branch with Rome A. Terwelp and Carl N. Adams remaining in their present capacities of factory manager and assistant manager in charge of the office, respectively.

QUIMBY
SUMP PUMP
A Cinch for Water Service
BECAUSE IT WAS DESIGNED FOR HEAVY DUTY
Originally designed for heavy chemical services, this unusually rugged pump finds water service easy going. Its extra-heavy construction reduces vibration to a minimum, insures long life, and provides against frequent shut-downs for repair. For quick details, ask for Bulletin C-209. If you have a pumping problem, phone the nearest Porter office for a Quimby Engineer. He will give you data and information based on 50 years experience in the pumping field.
QUIMBY PUMPS
H. K. PORTER
COMPANY, Inc.
PITTSBURGH 22, PENNSYLVANIA
QUIMBY PUMP DIVISION
340 THOMAS ST., NEWARK, N. J.
Factories: Newark, N. J. • New Brunswick, N. J. • Pittsburgh, Pa.
McKeesport, Pa. • Blairsville, Pa. • Mt. Vernon, Ill.

Quaker Improved Chlorinated Lime

Although still in demand for military needs, the Pennsylvania Salt Co. has announced that its Quaker Improved Chlorinated Lime is now available for civilian uses. This material conforms to Chemical Warfare Service Specifications No. 197-54-281B, Grade II.

New methods of controlling manufacture demanded by military needs have resulted in a material having better stability characteristics, more uniformity and a lower moisture content. Further information on the material may be obtained from the Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

G. James Joins Phipps & Bird

Mr. Lloyd C. Bird, Pres. of Phipps and Bird, of Richmond, Va., has announced that Garland James is now associated with the company as vice-president. Mr. James was formerly treasurer and superintendent of the Richmond Foundry and Manufacturing Co.

Yeomans Adds Mechanically Cleaned Bar Screens

Addition of mechanically-cleaned bar screens to its line of sewage treatment equipment has been announced by Yeomans Brothers Company, Chicago. These screens which include angle and vertical types may be operated either automatically or manually, with open, semi-enclosed or fully-enclosed varieties available.

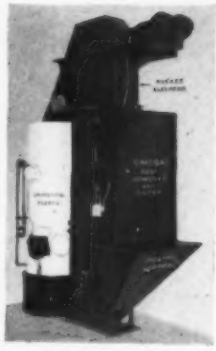
One feature of the Yeomans screens is the arrangement of the spring-steel cleaning fingers in relation to the fixed bars of the bar rack. Each fixed bar at the bottom is offset, permitting the fingers of the rake head to enter the fixed-bar apertures and make sliding contact with each bar. It is this action which cleans the bar screens.

The rake head is held fixed and rigid throughout the full upward travel and then automatically discharges at point of disposal from the screen. On the downward travel the rake head is again locked in the cleaning position. It cannot tilt or climb over screenings. Bull. 6900 which gives detailed information on the screens, and detail drawings may be obtained from Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

Maritime "M's" to Chicago Pump and Homestead Valve

Homestead Valve Mfg. Co., Coraopolis, Pa., has received its fourth star to be added to its "M" pennant and the Chicago Pump Co. has just received its Maritime "M" Flag. The Chicago Pump Co. award was for engineering results accomplished with the "Flush-Kleen" sewage pumping system and centrifugal marine pumps for circulating condensate and bilge services.

OMEGA
Chemical Feeders
A COMPLETE LINE



UNIVERSAL

The illustration shows a Universal Feeder with lead lined dissolving chamber, stainless steel high speed mixer, and Rotameter on water supply. These accessories recommended for feeding Ferrisul, Ferrifloc and low grade alum. Included also is a bucket elevator for use where overhead storage is not available. Note low and high level controls on feeder and elevator housings. Dust remover makes hopper charging a completely dustless operation. Complete chemical feeding systems are engineered and built to fit the job.

LOSS-IN-WEIGHT TYPE GRAVIMETRIC

This is without a doubt the most accurate type chemical feeder made. Indicates the weight of material in the hopper at all times on the scale beam. Feeds lump, granular or powdered materials at 100 different rates by increments of 1% of the maximum rate of feed. No calibration is required. The rate of feed is automatically controlled by the loss in weight in the hopper of material. Records every pound of material delivered by the feeder on a mechanical counter geared to the lead screw which retracts the counterpoise.

The size No. 1 feeder illustrated feeds up to 2000 pounds per hour.

PRECISION SOLUTION FEEDER

Not an orifice feeder but a true Volumetric feeder of the most accurate type for feeding solutions of Calgon, Hypochlorite, Copper-Sulphate, Ammonium Sulphate, etc. Feeding range 100 to 1, from 1/25 to 200 gallons per hour. Standard tank sizes, 25 to 200 gallons. Where electricity is not available, eight-day spring motors are used; meter-paced control is easily accomplished for flow proportional feeding.

500 LB./HR. SLAKER FEEDER AND 500 LB./HR. SLAKER

A feeder of extreme accuracy, weighing material continuously on a short conveyor belt carried on sensitive scales. Can be set by a single dial to feed within 2% of the desired rate, and any departure from weight per unit of volume is automatically compensated. Alarms prevent over or under feeding; totalizer and recorder keep complete records of material fed. (Bin gates and extension hoppers not shown but available to specifications).

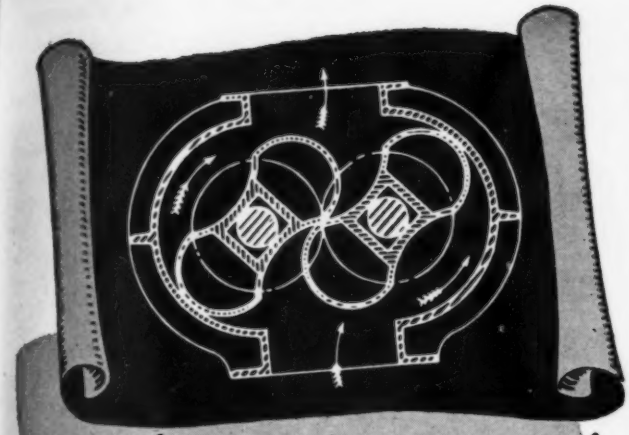
Bulletins on request

Sincerely

OMEGA MACHINE COMPANY

(Division of Builders Iron Foundry))

10 CODDING ST. **PROVIDENCE 1, R. I.**



Here's the inside story of the POTTSTOWN AIR BLOWER

Notice how the two interengaging impellers of the POTTSTOWN Rotary Blower rotate in opposite directions. The concave portion of each impeller alternately carries along a pocket of clean air as it passes over the bottom inlet. This impulse of air is swept half around the interior of the casing wall and then forced through the top outlet. At operating speeds these alternating impulses merge into a continuous flow of air to your diffusers. The impellers are interengaged by timing gears operating in an external sealed-case oil bath.

Efficient positive displacement is accomplished with POTTSTOWN Blowers because their precision machining permits close tolerances of only .003" on moving parts. Their efficiency is maintained during long life because there is *no actual contact or surface friction* between the impellers themselves—nor between impellers and casing interior. *No wearing parts here!*

With friction eliminated, interior lubrication is unnecessary. Only clean air — uncontaminated by lubrication — is delivered to the diffusers in your sludge tanks. No valves, springs, pistons, sliding vanes, or other friction parts to wear out or cause repairs. *THAT'S the inside story of the POTTSTOWN Blower!*

Simplicity of design—sturdy construction—precision machines—THESE FEATURES eliminate maintenance and adjustments, *even on daily 24-hour service!*

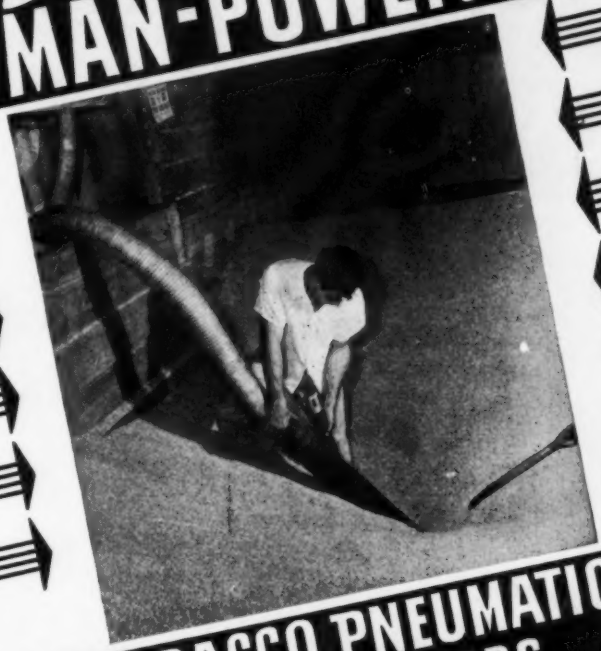
End view of blower with headplate removed to show impellers and precision machining.

Write today for our new Bulletin No. P-100.

ALLEN BILLMYRE COMPANY, 449 Fayette Avenue, Mamaroneck, N. Y.

POTTSTOWN
ROTARY POSITIVE DISPLACEMENT
BLOWERS AND EXHAUSTERS

Save... MAN-POWER



With DRACCO PNEUMATIC CONVEYORS

The following chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime, soda ash, auxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

A PARTIAL LIST OF *DRACCO* INSTALLATIONS

FRIDLEY FILTRATION PLANT	Minneapolis, Minn.
DALECARLIA FILTRATION PLANT	Washington, D. C.
MUNICIPAL WATER SOFTENING PLANT	Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT	Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
MUNICIPAL WATER PLANT	Columbus, Ohio
MUNICIPAL WATER PLANT	Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT	Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT	Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
MINNEAPOLIS-SAINT PAUL SANITARY DISTRICT (Sewage Disposal Plant, 2 installations)	St. Paul, Minn.
MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT	Denver, Colorado
MUNICIPAL WATER PLANT	Covington, Ky.
MUNICIPAL WATER PLANT	Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT	Atlanta, Ga.
SEWAGE DISPOSL PLANT (2 installations)	Cleveland, Ohio
MUNICIPAL WATER PLANT	Benton Harbor, Mich.
MUNICIPAL WATER PLANT	Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich.
MUNICIPAL WATER PLANT	Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
CITY OF GRAND FORKS	Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT	Pittsburgh, Pennsylvania
WATER FILTRATION PLANT	Wichita, Kansas
INDIANAPOLIS WATER CO.	Indianapolis, Ind.
WATER FILTRATION PLANT	Appleton, Wis.
MUNICIPAL WATER PLANT	Chillicothe, Ohio

And a large number of installations in water works of Ordnance Plants

Write for Bulletin No. 526

DRACCO CORPORATION

4079 E. 116th St., Cleveland 5, O. • New York Office, 130 W. 42nd St.

PNEUMATIC CONVEYORS • DUST COLLECTORS

HILL-HUBBELL
FACTORY PROCESSED STEEL PIPE PROTECTION
is TIME SAVING

Specify **HILL-HUBBELL** *in your plans*

SPECIFICATION TQA-1
MEETS AWWA-7A-6

Biturine Akwalining assures HIGH "C" factor, prevents tuberculation, corrosion, incrustation and silting. Mechanically applied multiple lining by spinning pipe, assures even distribution and perfect bond.

FACTORY PROCESSED PIPE IS READY TO INSTALL

HILL-HUBBELL processed Steel Pipe has three big advantages over the field job. No. 1—Multiple coated—and—wrapped protection is applied at our factory, the pipe is delivered ready to install, thus *saving time*. No. 2—Pipe line engineers can figure time costs more accurately in advance, because of less risk of delay. No. 3—HILL-HUBBELL standardized pipe protection will give longer service life.

GENERAL PAINT CORPORATION
HILL, HUBBELL & CO. • Division • Cleveland, Ohio
• EXPORT OFFICE: SAN FRANCISCO, CALIFORNIA, U. S. A. •

Mathieson Makes Vincent Technical Director

Dr. G. P. Vincent, Mgr. of Sales Development and Tech. Serv. of the Mathieson Alkali Works, has been appointed to the newly created position of Technical Director. In addition to his former duties, Dr. Vincent will direct research and technical development and advise on technical matters concerning plant operation.

G. P. Vincent

R. E. Gage

In these latter capacities, Dr. Vincent succeeds R. E. Gage, who was Dir. of Research and Development for fourteen years. Mr. Gage has been appointed technical advisor to the company.

Dr. Vincent is known in the water works field for his work on sodium chlorite and chlorine dioxide for water treatment, and a paper which he co-authored on this subject appears in the Reference and Data Section of this issue.

M-S-A Philadelphia Office Moves

Since the middle of April, this year, the Philadelphia office of the Mine Safety Appliances Co. has been located at 5564 Baltimore Ave., Philadelphia 43, Pa.

IMPROVED JOINTING COMPOUND

Tegul-MINERALEAD

for Bell & Spigot Main

- Sulphur base; quick sealing, speeding laying and backfilling.
- 10 lb. ingot form, easily handled, stored and shipped. Impervious to rain. Cannot change composition.
- Makes permanently tight joints. Goes 3 to 5 times as far as lead, helping conserve a strategic war metal.
- For money-saving information, write

The ATLAS MINERAL Products Company of Pa.
Mertztown Pennsylvania

..for ACCURACY and TROUBLE-FREE OPERATION

INSIST ON THE WILSON HYPO-CHLORINATOR

Engineered and Manufactured by

WILSON
CHEMICAL FEEDERS, INC.
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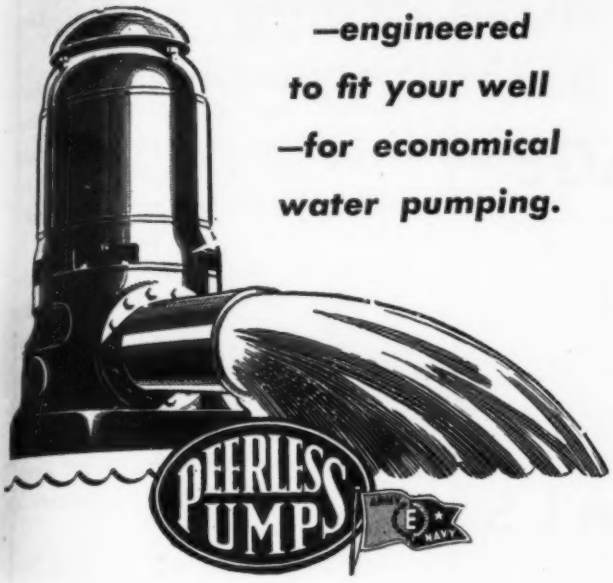
EDSON
DIAPHRAGM PUMPS

Hand Sizes 2", 2½", 3", 4"
Power Sizes 3" and 4"
Open Discharge or Force Pump
Edson Special Suction Hose
Red Seal Diaphragms
Strainers and Foot Valves
Hose Spanners—Adapters

THE EDSON CORPORATION
Main Office and Works: 49 D St. South Boston, Mass.
New York: 142 Ashland Pl., Brooklyn

The "well-rated" pump

—engineered to fit your well —for economical water pumping.



A good water well is an asset worth many times its cost. But a well is no better than its pump. By installing a Peerless Turbine Pump you get the fullest value from your well because the pump is engineered to *fit your well.*

FIRST IN QUALITY—Peerless design and construction reflect the finest engineering. The design is a proved success, demonstrated by the thousands of Peerless Pumps operating in every field. Embodying the finest materials, Peerless construction reflects the highest standard of quality.

FIRST IN ECONOMY—Peerless Pumps maintain their original efficiencies far beyond normal, due to their advanced design. Double bowl bearings, double impeller seals, precision finish of runner vanes and seasoned castings insure accuracy of fit and smooth running for years to come.

FIRST IN DURABILITY—Peerless Pumps are noted for their long life—years of extra service, due to their precision workmanship and rugged stability.

Capacities — 10 to 220,000 gallons per minute.

Peerless Turbine Pumps can be installed in deep or shallow wells—operating by direct connected electric motor, geared or belted head—for pumping into pressure main, elevated tank or into open reservoir.

Peerless Distributors and Direct Factory Representatives are located in every State.

PEERLESS PUMPS

PEERLESS PUMP DIVISION
Food Machinery Corporation

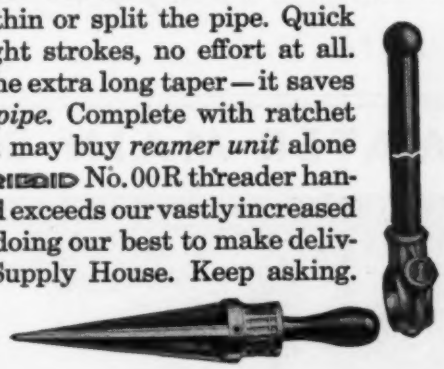
TURBINE
HI-LIFT
HYDRO-FOIL

301 W. Ave. 26, Los Angeles 31, Calif. • 1250 Camden Ave. S.W., Canton 6, Ohio • Other Factories: San Jose 5, Fresno 16, Calif.

Extra Long Taper of the new RIDGID LonGriP Pipe Reamer

means *safe, easy reaming of burr only*

• It cuts the burr out clean as a whistle—but it doesn't gouge, thin or split the pipe. Quick easy feather-light strokes, no effort at all. The trick is in the extra long taper—it saves you work *and pipe.* Complete with ratchet handle—or you may buy *reamer unit* alone for use in your RIDGID No. 00R threader handle. War demand exceeds our vastly increased output—we're doing our best to make deliveries to your Supply House. Keep asking.



Reamer unit fits No. 00R ratchet threader handle.

RIDGID

WORK-SAVER PIPE TOOLS

THE RIDGE TOOL COMPANY • ELYRIA, OHIO, U. S. A.

NORIT

A MESSAGE

to WATER WORKS OFFICIALS

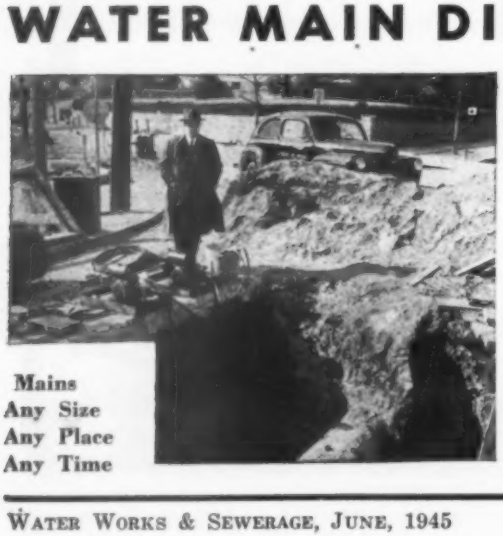
No peacetime industry has escaped the consequences of total war. Dislocations, restrictions, emergency regulations, shortages in labor and supplies, etc. have hampered operations for all, some suffering more severely than others.

As a result of war contingencies during these past few years which have been so hectic, the American Norit Co., Inc. has been forced to severely curtail its production. V-E Day doesn't seem to be far off now and with the cessation of hostilities, it is hoped that full scale production can be resumed, enabling us to meet all demands for NORIT with the same promptness as before the war.

AMERICAN NORIT COMPANY, INC.
Jacksonville Florida

Selling Agents:
L. A. SALOMON & BRO.
216 Pearl St. New York 7, N. Y.

WATER MAIN DISINFECTION



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Any Place
Any Time

Complete Service furnishing

Chlorinating Equipment
All Chemicals
and
Supervision of Chlorination

Call or Write for Estimate

LUTHER and WOOD
1427 Eye St., Washington 5, D. C.
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Westinghouse Votes Name Simplification

Also Splits Stock to Increase Availability to Greater Numbers

Stockholders of the Westinghouse Electric and Manufacturing Company at their recent annual meeting voted to split the company's stock on the basis of four shares of new stock for one of old. Also it was voted to change the cumbersome name of the company merely to Westinghouse Electric Corp. for simplicity and brevity.

Purpose of the stock split is to broaden the base of Westinghouse ownership by making the stock available in greater number of shares at a lower price.

Authorized capital stock of the company today is 4,000,000 shares, consisting of 80,000 shares of preferred and 3,920,000 shares of common, all with a par value of $50.00. Total authorized shares of the new stock will be 16,000,000, of which—on the four-for-one basis—319,896 shares of preferred and 12,531,264 shares of common will be outstanding. Par value of the new stock, both preferred and common, will be $12.50.

Reclassification of the stock will not in any way change the preferences or relative rights of the stockholders and there will be no change in the terms of either the preferred or the common. Neither will the reclassification of the shares result in any change in the capital structure or surplus, or other accounts of the company.

There are now about 48,000 Westinghouse stockholders and none owns more than 1.5 per cent of the stock.

WESTON

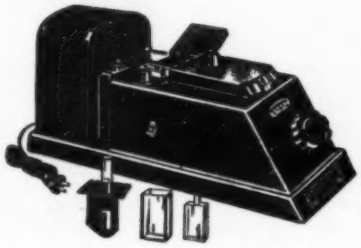
GASKET AND FORM
The Perfected Method for Making
Sewer Pipe Joints of Cement

- No jute used—gasket centers spigot.
- Definite space in each joint for cement.
- Form confines cement-grout to lower portion of joint.
- Particularly advantageous in water-bearing trenches.
- Infiltration minimized.

L. A. WESTON Adams, Mass.

KLETT SUMMERSON ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis

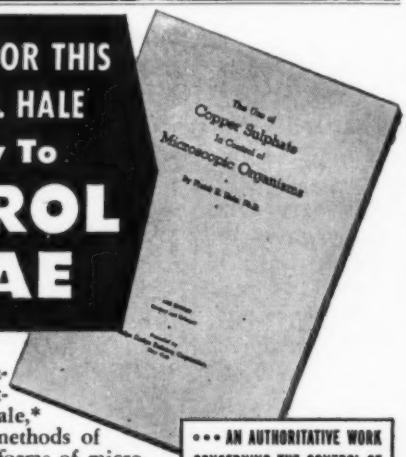


Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined.

KLETT MANUFACTURING CO.

179 EAST 87th STREET • NEW YORK 28, N. Y.

FREE WRITE FOR THIS BOOK BY DR. HALE Tells How To **CONTROL ALGAE**



This revised and enlarged edition, written by Dr. Frank E. Hale,* describes in detail methods of controlling various forms of microscopic life commonly dealt with in water supply systems. Descriptive material includes 48 clear photomicrograph studies of organisms discussed. Simplified methods of applying copper sulphate are also shown. ... Many of the most important water works specify Nichols *Triangle Brand* Copper Sulphate. Triangle Brand is available in several convenient sizes for water treatment. Write *today* for details and book.

*(Director of Laboratories, Dept. of Water Supply, City of New York

••• AN AUTHORITATIVE WORK CONCERNING THE CONTROL OF MICRO-ORGANISMS AND ELIMINATION OF TASTES AND ODORS

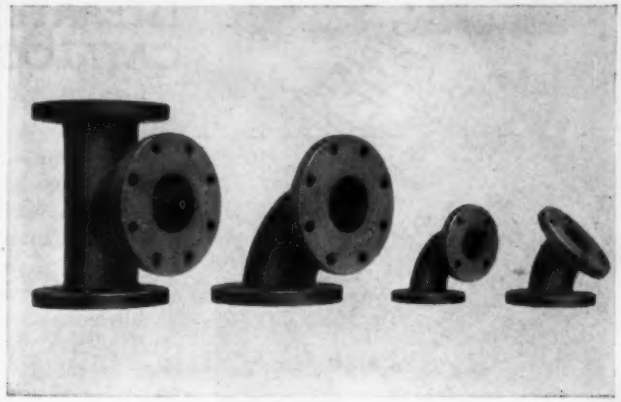
FOR YOUR REQUIREMENTS SPECIFY **NICHOLS TRIANGLE BRAND COPPER SULPHATE** 99% + PURE THE STANDARD FOR OVER 50 YEARS

MADE BY

PHELPS DODGE REFINING CORPORATION

Electrolytic Refiners of Copper

40 WALL STREET, NEW YORK 5, N. Y. • 230 N. MICHIGAN AVE., CHICAGO 1, ILL.



ACE SOLID HARD RUBBER PIPE: Sizes ¼" to 8". ACE HARD RUBBER LINED PIPE: Sizes 1¼" and up. ACE HARD RUBBER FITTINGS: Threaded type, ¼" to 6". Flanged type, 1½" to 8".

AMERICAN HARD RUBBER COMPANY

presents

ACE RUBBER and SARAN

PROTECTION AGAINST CORROSION

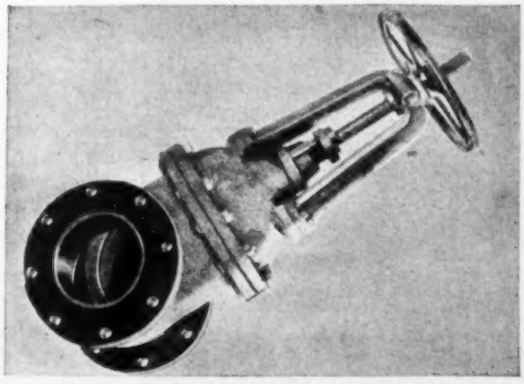
A complete line of equipment, proofed against corrosion! Provided in a two-fold Ace service: 1. A protective surface over metal tanks and parts, and 2. Solid hard rubber and Saran molded parts. Tank lining material used may be Ace rubber, both soft and hard, Thiokol, Neoprene and other synthetic rubbers.

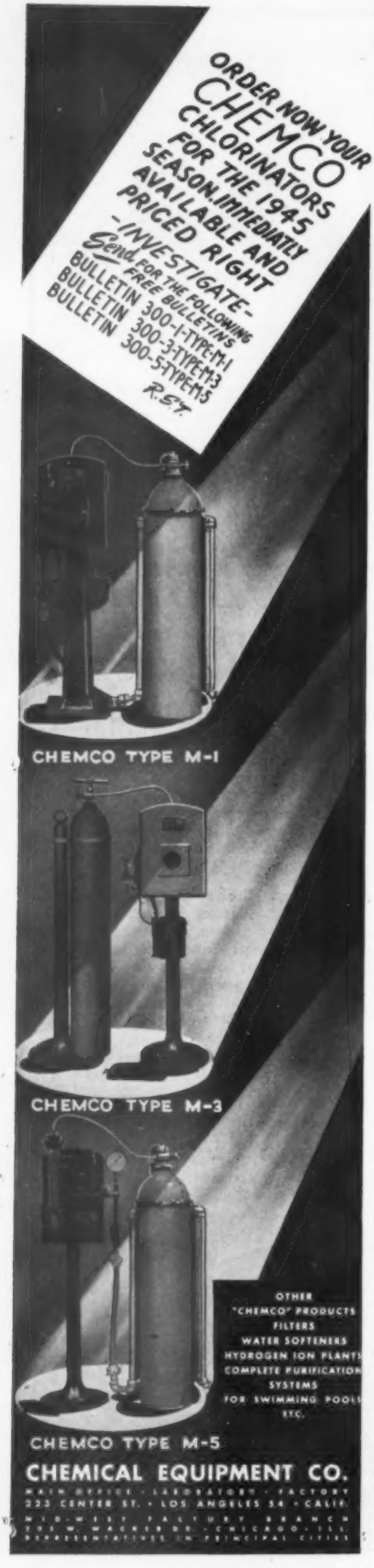
Illustrated are Ace Hard Rubber Flanged Pipe Fittings and Ace Hard Rubber Lined Gate Valves. There are many other products, including storage tanks, pumps, filters, agitators, etc. Our engineers are at our service . . . backed by the experience gained in working on most of America's successful sewage disposal and water purification installations.

AMERICAN HARD RUBBER COMPANY

11 Mercer St., New York 13, N. Y. Akron 9, Ohio
111 West Washington Street, Chicago 2, Ill.

VALVES. Gate, diaphragm and check valves with perfectly bonded rubber protection for all surfaces in contact with corrosive solutions.





LITERATURE AND CATALOGS

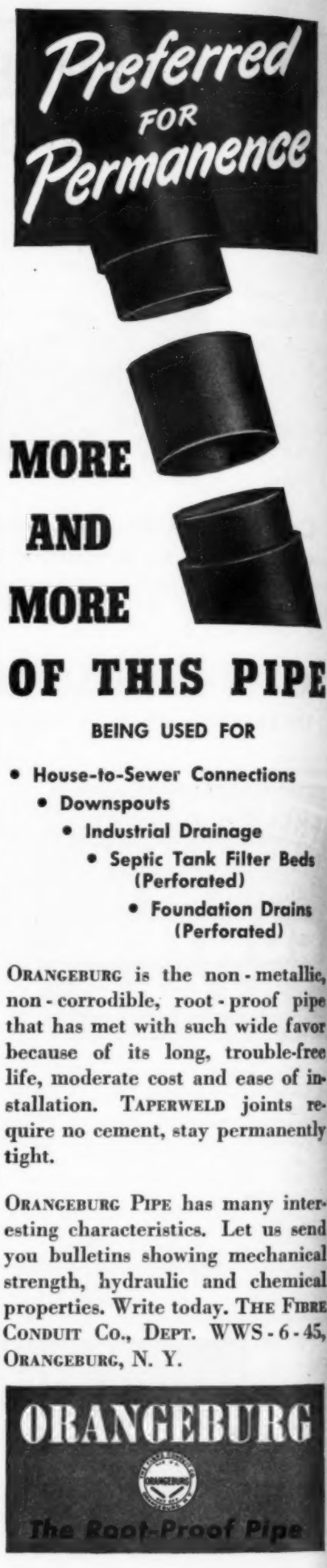
For a number of years now, we've been a consistent reader of Ray Sparling's **Metrograms,** and there have been many occasions when in the course of preparing a lecture, we have used Mr. Sparling's Metrogram as source material. It's hard then to realize that in the 26 months we've been writing this section of *Water Works and Sewerage* we have failed to mention **Sparling's Metrograms** once.

Mentioning it three times in the above paragraph hardly makes up for the previous omission, for if you don't know about this four page mimeographed folder issued monthly, you certainly should be told in order that you may have your name put on the mailing list. For this little item is more than a piece of direct mail advertising— it is an encyclopedia of interesting information about water in civilization from prehistoric times to the future; it is a source of jokes, some good, some bad; it is a news paper; and it nearly always contains a good editorial written in short, short story dialogue form about the trials, tribulations and successes of one Tom, Asst. Supt. at Jordantown and Cappy Tolliver of Dimesville. Of course there's always something about Sparling meters installed somewhere, but even that is interestingly done and we can recommend you write Sparling at Los Angeles, Cal., if you'd like something good to read besides *Water Works and Sewerage.*

* * *

Today, in modern slang, if your statement has the approval of your listener, he most likely will say, "Now you're cookin' with gas," or some such alleged witticism, but a decade or more ago "Amos and Andy" had most of the radio listening public saying "Check and Double Check" for anything that was O.K. Now **Rensselaer check valves** have nothing to do with current or past slang but from the pictures shown and data and information listed in Bull. V-1, these check valves must be O.K.

For example, there is List 340, the Clearway Quiet Closing Check Valve which eliminates "slamming" and has 11 other "points of superiority." Then there are List 37, standard swing check valves; List


Preferred FOR Permanence
MORE AND MORE OF THIS PIPE
BEING USED FOR
• House-to-Sewer Connections
• Downspouts
• Industrial Drainage
• Septic Tank Filter Beds (Perforated)
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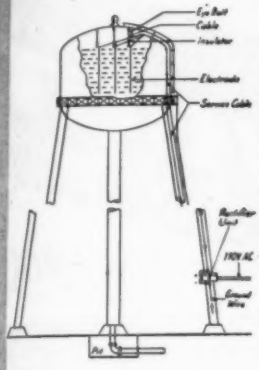
ORANGEBURG is the non-metallic, non-corrodible, root-proof pipe that has met with such wide favor because of its long, trouble-free life, moderate cost and ease of installation. TAPERWELD joints require no cement, stay permanently tight.
ORANGEBURG PIPE has many interesting characteristics. Let us send you bulletins showing mechanical strength, hydraulic and chemical properties. Write today. THE FIBRE CONDUIT CO., DEPT. WWS-6-45, ORANGEBURG, N. Y.
ORANGEBURG
The Root-Proof Pipe

HOW TO RUST-PROOF SUBMERGED METALS... *Permanently*

DC electric current of low voltage, low amperage, properly balanced and controlled as required by the water through which it passes and the metal it is to protect, prevents corrosion of the metal by oxygen in the water. It therefore *stops rust formation by oxidation.* This is the Electro Rust-Proofing System of Cathodic Protection. It has been applied to thousands of tanks, standpipes, deep wells, flocculators and many other types of water storage and water handling equipment. It is *engineered* to every installation. It stops the formation of rust below the water line totally and permanently, therefore kills the greatest single item of tank maintenance cost, the major cause of tank depreciation. Recognized and advocated by independent authorities. Write for free data.



ELECTRO RUST-PROOFING *Corporation*

DAYTON 10, OHIO, U. S. A.

TYPE "A" DAYTON-DOWD CENTRIFUGAL PUMP

- WATERWORKS
- INDUSTRIAL PLANTS
- FILTRATION PLANTS
- MINES, ETC.

For general continuous duty

PUMPING SERVICE

TYPES — Single stage, single suction, sizes 2" and 3". Single stage, double suction, sizes 2½" to 42". Capacities up to 60,000 G.P.M.

SPLIT CASE DESIGN — For easy accessibility. Available in either cast iron, chrome iron, cast steel, bronze, monel and other alloys.

IMPELLER — High efficiency design. Made of cast bronze. Also available in KA-2 stainless steel, cast carbon steel, monel or other alloys.

DRIVE UNITS — Pumps can be supplied with dual drive hookup; electric motor and steam turbine; electric motor and gas engine. Twin pumps also available with one electric motor.

FREE DATA BOOK. Write on your business letterhead for FREE data book and catalog. Address DAYTON-DOWD Company, Dept. S-15, Quincy, Illinois.

DAYTON-DOWD

Turbine Pumps • Centrifugal Pumps

INSTALLATIONS WORLD WIDE

LARGEST CITY TO SMALLEST VILLAGE

VALVES COMPLETE EQUIPMENT FOR WATER WORKS FILTRATION AND SEWAGE DISPOSAL PLANTS LATEST "COREY TYPE" **HYDRANTS**

Write for Catalogue and Information

IOWA VALVE CO.

General Offices:
Hubbell Bldg., Des Moines, Iowa

Plant:
Oskaloosa, Iowa

CONTACT

LAKESIDE ENGINEERING CORPORATION

Chicago 6 **Illinois**
222 West Adams St.

FOR

WATER SOFTENING by the Zeolite or Lime-soda methods.

WATER FILTERING to remove Suspended solids, color, odor or taste.

SEWAGE TREATMENT by the Aero-filter which offers all of the advantages of other types of trickling filters plus better momentary distribution.

Spiraflo Clarifier for improved clarification, including scum and oil removal.

BE PREPARED FOR THOSE FIRES

Here is a fire hydrant that goes into action FAST! Designed to deliver plenty of water in a hurry. Helps cut fire losses and saves your city money. For the full story on MUELLER-COLUMBIAN Fire Hydrants write for our latest four-page folder. All the facts — condensed for quick reading.

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WATER WORKS ENGINEERS
DEPEND ON
Taylor
LIQUITROL
THE MODERN METHOD TO CONTROL
pH, CHLORINE AND PHOSPHATES

Taylor Liquitrol is the scientific method for determining pH and Chlorine values in water . . . and includes the one compact complete unit that meets all requirements for accurate determinations by water and sewage engineers and chemists.

The Taylor Liquitrol Method requires no costly investment in laboratory facilities. It includes Taylor Comparators from $16.00 up, with color standards guaranteed unconditionally against fading, specifically designed for water works determinations.

Send for free book. 84 pages of latest facts, procedures and Taylor Liquitrol methods and outfits. See your dealer or write direct.

W. A. TAYLOR AND CO.
7308 YORK RD. • BALTIMORE 4, MD.

PITTSBURGH
ARCTIC
(ALSO MADE IN SPLIT-CASE TROPIC)
METERS
NUTATING
DISC
TYPE
For the ultimate in disc meter satisfaction. Rigid manufacturing controls, skilled assembly, and exacting test make these meters top dollar value in the general service field. Made in sizes 5/8", 5/8 x 3/4", 3/4", and 1".
Pittsburgh Equitable Meter Co.
Pittsburgh 8, Penna.

370 Quiet Closing Check Valves; and List 39, heavy pressure check valves, each of which has its particular uses and advantages.

Bull. V-1 also shows pictures of yoke valves, gate valves, fire hydrants, floor stand valves, motor operated valves, and several other units about which one may also say "Check and Double Check." For your catalog files check Bull. V-1 of the Renssalaer Valve Co., Troy, N. Y.

* * *

If you have ever tried to control the flow of milk of lime solution, particularly at low rates of feed, you have had your share of headaches. According to a large catalog sheet (folded for mailing), issued by Hills McCanna Co., **Hills-McCanna (Saunders Patent) Valves** will eliminate the difficulty to which you have been accustomed.

This sheet shows a large cutaway view of the diaphragm valve which is "designed to overcome the limitations of plug cocks, gate and globe valves." Available in rubber lined, glass lined, lead lined, alloy bodies, chain operated, angle types, etc., these valves have no stuffing boxes or stem packing, no pockets or ports to accumulate material, no dependence on metal to metal seating, and many other advantages. Both air and water models are available with either rising or non-rising stem. There is also a quick opening type.

It is claimed that there are more than 500 service applications, and we can think of a lot of them in both water and sewage plants, not the least of which is handling lime solutions in sludge conditioning plants, or on sludge, gas, air or water lines for that matter. The Hills-McCanna Co. will be glad to send you one of these sheets or other information on these valves if you will write them at 2349 Nelson St., Chicago, Ill.

* * *

If what we read in the March, 1945 issue of *Paper Trade Journal* on **"The Use of Activated Silica in the Coagulation of Highly Colored Water"** by R. E. Noreus, is true, then it appears that the industrial water producers are taking up with this treatment much more rapidly than are municipal water works. Now this is no ballyhoo on our part about the use of Activated Silica, for we believe that the process should stand on its own merits, but

WRITE FOR INFORMATION
VOGT BROTHERS TRAFFIC MODEL FIRE HYDRANT
A.W.W.A.
VOGT BROTHERS MFG. CO. Incorporated LOUISVILLE, KY.
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VOGT
VOGT MFG. CO., Incorporated LOUISVILLE, KY.
P. O. BOX 1122
AERO-MIX
AERATOR—MIXER
A Size and Type to Fit Your Problem in Water or Sewage Treatment.
WRITE FOR INFORMATION

LEADITE
The Pioneer Self-Caulking Material for C.I. Pipe
W N S E
USED MOST EVERYWHERE!
Hundreds of water works men have used Leadite . . . saved with Leadite . . . proved the dependability of Leadite under most all conditions of bell and spigot water main construction.
THE LEADITE COMPANY
Girard Trust Co. Bldg., Philadelphia 2, Pa.
No Caulking

it is interesting to note that where a high degree of water processing is necessary for the production of an industrial product, this silica treatment has been found successful.

Of course we should not forget that *Water Works and Sewerage* published the original work on activated silica and only a year ago published another comprehensive article on the subject but the point that struck us in this case was the appearance of an article on the subject of water treatment in a trade journal not concerned with the production of water per se, but only as a tool in the major industry being described. Without attempting to review the contents of the paper we can say that it should be of considerable interest to any one interested in the possibilities of activated silica in water coagulation.

* * *

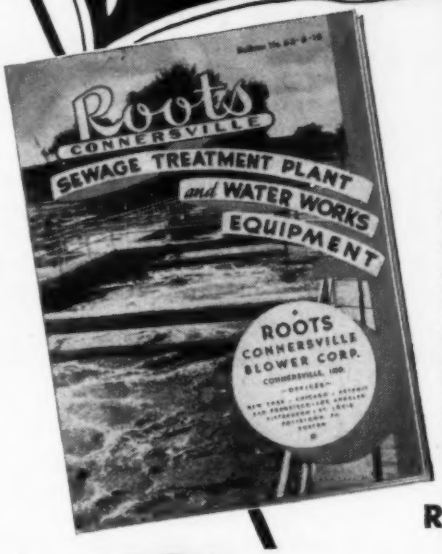
In a four-page folder the Buffalo Gasoline Motor Co. presents a good argument for **Buffalo Gas and Gasoline Engines** as standby power in flood protection works. The pictures show locations of pumping stations powered by these gasoline or gas engines in flood areas, where, during high waters, it is often necessary to pump drainage from a townsite up to the level of the stream which flows by, high above. Installations in Tennessee, Connecticut, and Massachusets are shown. We know a number of sewage plants in the mid-west that could also use some good standby pumping units to keep the water outside the dikes.

For that matter these motors and engines need not be confined to flood water pumping but are, or can be, standby producers of electricity in case of power failure for any other reason than floods. From the folder it appears that all sizes of engines are available from 85 to over 300 bhp. and they can be connected to vertical and horizontal centrifugal pumps, generators, or deep well pumps. This folder and other information may be obtained by writing to the Buffalo Gasolene Motor Co., 1280-90 Niagara St., Buffalo 13, N. Y.

* * *

Here's an interesting and helpful new booklet—just off the press, issued by the Reilly Tar and Chemical Corp. of Indianapolis, Ind.

you need this BULLETIN



for
CORRECT PLANNING
and SPECIFYING

It gives much interesting and helpful information on positive displacement and centrifugal aerating blowers, positive displacement digester gas meters, and filter vacuum pumps. The vital part played by air in sewage treatment is explained, together with the advantages of various types, drives, etc. Typical "R-C" installations are also shown. We have a copy of Bulletin 23-B-12 for you.

ROOTS-CONNERSVILLE
BLOWER CORP.
One of the Dresser Industries
506 Mount Avenue Connersville, Ind.

Roots CONNERSVILLE SINCE 1854
Rotary Positive & Centrifugal
AIR and GAS
HANDLING EQUIPMENT

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Recent preference indications from hundreds of water works superintendents everywhere show RENSSELAERS (Coreys 'til 1942) as leading.

Some of the reasons for this preference are given in our Bulletin W. May we send it to you?

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Troy, N. Y.

The FORD Copperhorn

Here's your modern meter setting for modern basements. All brass and copper, it is attractive in appearance, lasts a lifetime, minimizes pressure losses. The COPPERHORN is easy to install, putting the meter at the desired height, in the proper position, requiring no meter couplings or pipe fittings.

When you remove the meter you leave the customer's pipe physically connected and supported, — electrically bonded. Here's trouble insurance in meter changing.

Hundreds of water works have standardized on the COPPERHORN. Hundreds of thousands are in service. Learn more about this modern meter mounting.

Ask for our catalog and a sample COPPERHORN.

FORD METER BOX CO., WABASH, IND.

Naturally, it is named **Reilly Protective Coatings** and it tells about these protective coatings for metal, brick, cement and wood surfaces. The bulletin also describes Creocote Paint for creosoted wood block floors, poles, guard rails, and posts.

In addition to some excellent photographs of water transportation lines and water works systems, there is considerable information of interest on these materials, and their application. A copy of this booklet, Bull. No. 2-PC-45, may be obtained by writing to Reilly Tar and Chemical Corp., Merchants Bank Bldg., Indianapolis 4, Ind.

* * *

"Put your storage tank, processing vessel or structural steel problems up to the Stacey Bros. Gas Construction Co., Cincinnati, O." This is the theme of a comprehensive picture story of the fabrication and erection of gas holders, storage tanks, processing vessels, and other structures contained in **General Bulletin G-45** of the company—one of the Dresser Industries.

Available on request, the 44-page bulletin shows the company's production and erection facilities in action, and illustrates in detail many of the products such as gas holders, storage tanks, and processing equipment which Stacey Bros. builds for the gas, petroleum, chemical and food industries, or water and sewage plants, too, for that matter.

* * *

If you have never had positive displacement blowers explained, here is your opportunity to learn, for Bull. No. P100 of the Pottstown Blower Co. describes the principle of operation and design of the **Pottstown Rotary Displacement Blowers.** This new 16-page bulletin is issued by the Allen Billmyre Co. Also described in the bulletin are the units designed for services where volume of air must remain constant under variations in pressure and vacuum. Included in the services to which these units are put, *besides sewage disposal plants,* are agitation of liquids, air blast cleaning, pneumatic conveying, vacuum cleaning, gas and oil burners.

Of course, the bulletin is illustrated with drawings and pictures, and contains tables of capacity and technical data. Bull. No. P100 may be obtained by writing Pottstown Blower Co., Division of Allen Billmyre Co., 431 Fayette Ave., Marmaroneck, N. Y.

The FORD COPPERSETTER

A complete meter mounting, all brass and copper, for service lines of moderate depth.

The COPPERSETTER replaces meter couplings, valve, risers and ells. It saves the making of joints. Installed as a unit, it requires no meter blank or measuring to leave the proper space for meter.

There is nothing to rust out on the COPPERSETTER. It cuts down pressure loss, assuring full flow through the meter. Meter changes are easy and trouble-free as the removal of the meter leaves the service pipe on inlet and outlet physically connected and held in line, the electrical bond unbroken.

COPPERSETTERS are made in heights from 6" to 36", with and without valve, for connecting to iron or copper pipe. Learn more about these modern fittings.

Send a postal card for our catalog. No obligation.

FORD METER BOX CO., WABASH, IND.

We remember back in the last war there was a song entitled "Everybody's Doing It." We don't recall that it applied to post war planning then, but it certainly could now. Almost daily there comes to our desk some news release, catalog, or brochure with that as the theme. One of the latest is **Sewage Disposal—A Post-War Backlog of $2,000,000,000.** This particular four page Bulletin S-5M-4-45, issued by the Valve Dept. of American Car and Foundry Co. directs attention to the use of a.c.f. Lubricated Plug Valves and their applications in sewage plants. A long list of installations is given as well as typical specifications for valves to be used on sludge, fuel oil, gas lines, sewage, lime solutions, etc. When you write for this bulletin, you might also ask for the complete Catalog 3 CS. The address is Am. Car and Foundry Co. (Valve Dept.), 30 Church St., New York 8, N. Y.

If you haven't been reading L. P. Sudrabin's articles on Cathodic Protection in *Water Works and Sewerage* or if you have read them and want a brief resumé of what cath-

---

Over 225 P.F.T. Floating Covers in War Service

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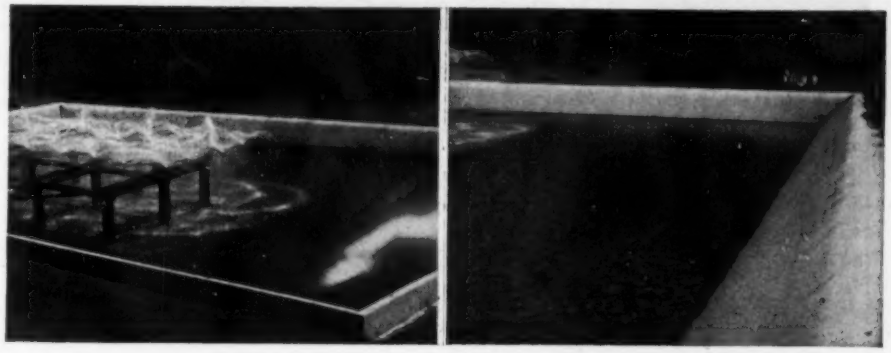
"GUNITE" CONTRACTORS
GENERAL OFFICES—ALLENTOWN, PENNA., U.S.A.



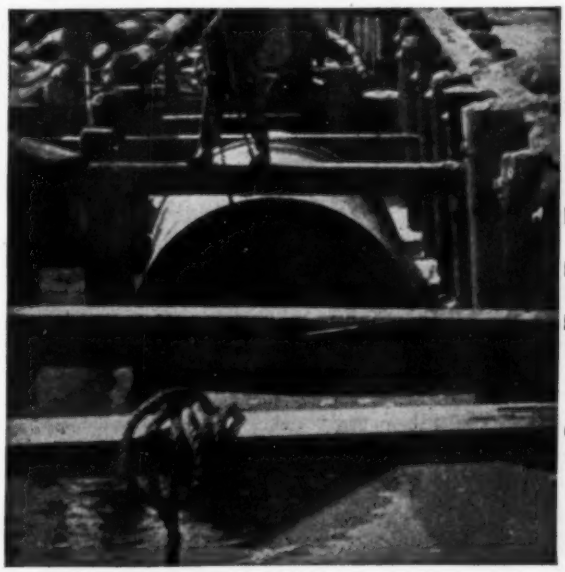
RESERVOIR RE-LINED WITH "GUNITE"

This is a filtered water reservoir at Charlottesville, Va., built many years ago and lined with concrete. It had disintegrated badly, and was leaking excessively in 1937.

Our Company was engaged to reline this structure during that year. The new lining consisted of two inch mesh reinforced "GUNITE" on the bottom and side slopes, and this entirely eliminated leakage. A recent inspection indicated that this work is still in perfect condition.

Many similar reservoir jobs and other "GUNITE" construction are described in our Bulletin C 2300. A copy will be sent to you upon request.

MANUFACTURERS OF THE "CEMENT GUN"



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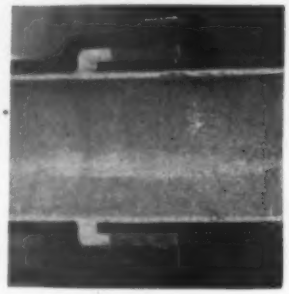
Restores efficiency of old Water Mains

Now **is the time to investigate the Tate Cement Lining process —and see what it can do to restore the efficiency of your old water mains.**



View showing Tate Process in Pipe Joint. Note thoroughness of Lining.

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odic protection is, then you may be interested in a folder entitled **Electro Rust Proofing System of Cathodic Protection.**

This folder answers questions regarding the cathodic method of protecting under-water metal surfaces against rusting. For example, these questions: What is it? What does it do? How is it applied? How does it operate? What is its operating cost? What is the original cost?

Several phases of the subject are presented including, among others, corrosion characteristics; method of corrosion control; tank protection, old and new; materials, equipment and component parts; current supply; savings, installation and insurance; and priorities, ordering and delivery.

All of this is contained in Form 12 which may be had from the Electro Rust-proofing Corp., Dayton 10, Ohio.

* * *

Perhaps browsing through a catalog isn't your idea of how to spend a rainy Sunday afternoon, but if you have any interest in pumps and speed reducers, and such, you won't be wasting your time while looking over the **Products of De Laval.** This Bull. 1181 is devoted to a complete

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Maybe you don't need an oil pump and maybe you aren't interested in the development of high pressure marine propulsion units, but you should be interested in the development of the centrifugal pumps for water works service. Copies of Catalog 1181 may be had simply by asking for them. Whom does one ask? The De Laval Steam Turbine Co., Trenton 2, N. J.

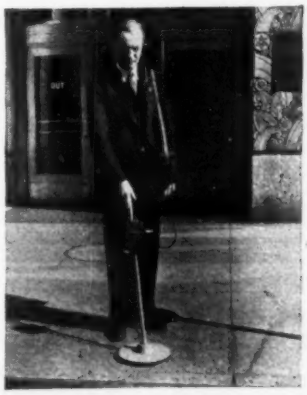
* * *

If you need any water hose you should write to B. F. Goodrich Co., Akron, Ohio for **Cat. Sections 4600 and 4800,** containing data on sizes, number of plies, weight per hundred feet, outside diameters and working pressures of water hose.

* * *

After reading in the March issue of the **Southwest Water Works Journal** that the 27th Texas Water Works and Sewerage Short School attracted 365 students, we are sorry that we were unable to accept an invitation to attend. The story of the meeting was written by Mrs.

"Bob White"
ELECTRONIC BOX LOCATOR



- Will locate curb and street boxes as fast as you can walk.
- Locates de-magnetized boxes where dipping needle fails.
- Finds boxes in the dark without a flashlight.

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In operators' opinions **"an invaluable aid"** in the control of stabilization and anti-corrosion treatment.

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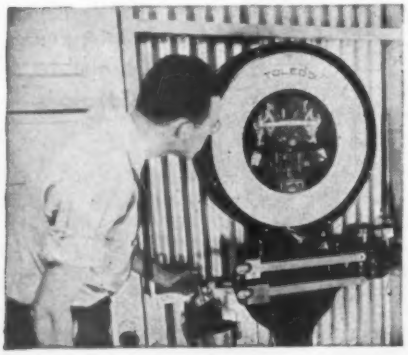

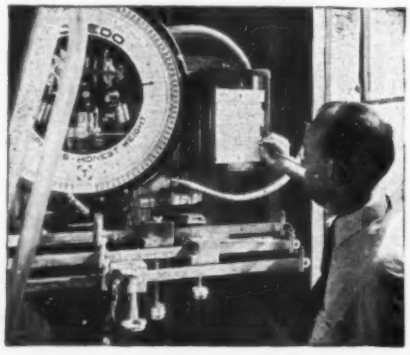

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Earl H. Goodwin, Asst. Secy. Treasurer of the Short School.

This Southwest Journal put out by the Gresham boys, Bob, Editor, and Hill, Bus. Mgr., can be counted on to contain a good article in addition to news and reports. This issue had an article on Lime-Zeolite Treatment and Stabilization with Polyphosphate by L. C. Billings, Supt. of Water and Sewage Treatment, Dallas. The Journal also contains the news that George J. Rohan has resigned as Secy.-Treas. of the Southwest Sect., AWWA, because he was leaving the position of Supt. of the Waco City Water Works to enter private business and didn't have the necessary time to give to the office.

* * *

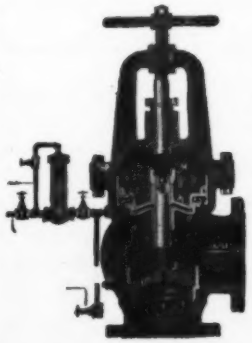
Almost on the heels of Albert Kozma's recent article in *Water Works and Sewerage*, on cathodic protection in a sewage plant, came Bulletin No. R-181, **Rusta Restor Rust Preventative,** describing the type of equipment and process that Mr. Kozma used.

This bulletin which discusses and illustrates the cathodic (i.e. electrical) method of preventing rusting may be had by writing The Johnson

Triple-Acting Non-Return Valve

This valve will automatically cut in a boiler whenever its pressure equals line-header pressure; it will isolate a boiler automatically whenever its pressure, from any cause, is lower than line-header pressure; and it will prevent steam flow from the boiler in event of sudden drop of line-header pressure below the boiler pressure, by means of differential shot pilot valve functioning.

Write for specifications.



Furnished in angle, globe and elbow patterns, sizes 2½" to 12"; also available in larger sizes, as well as in the Cross pattern.

GOLDEN-ANDERSON VALVE SPECIALTY CO.
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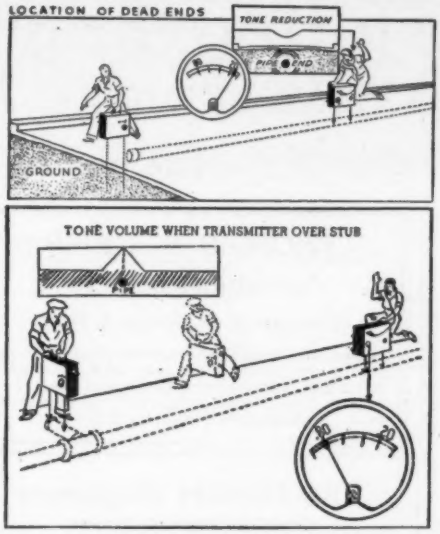
and Jennings Co., 864 Addison Road, Cleveland 14, Ohio. In addition to the explanation of the process, Bull. No. R-181 contains a table of comparative costs.

* * *

In the April issue of **Water**, published by the American Water Works and Electric Co., Inc., New York, N. Y., is a story about the appointment of Guy Waldrop as Chief Mechanical Engineer of the Water Works Service Co. Mr. Waldrop has been with the company since 1922 in various capacities. As Chief Mechanical Engr. we imagine that Mr. Waldrop was as interested as we were in the cartoon on the back page of that April issue. That cartoon depicted quite cleverly that "carelessness doesn't pay" and that "things should be done the safe way to enjoy life." "The worst start towards a safety record in water works history" is reflected in the figures for the first two months of the year; 2 deaths, 51 injuries, 22 lost time injuries, 12,438 lost time days. Fingers and toes lead with eye and back injuries tied for third.



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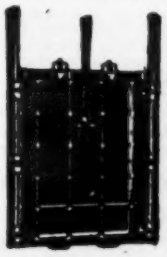

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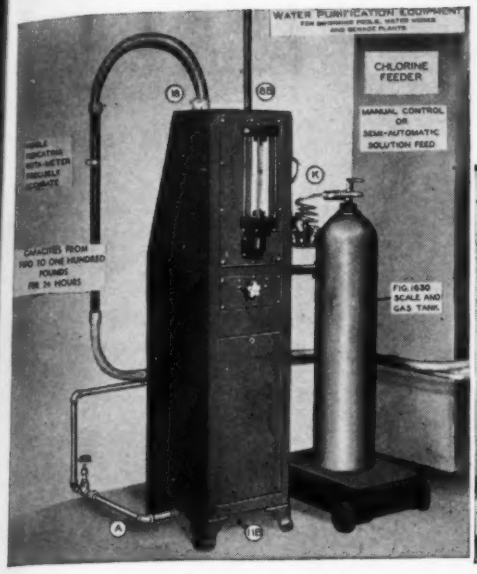
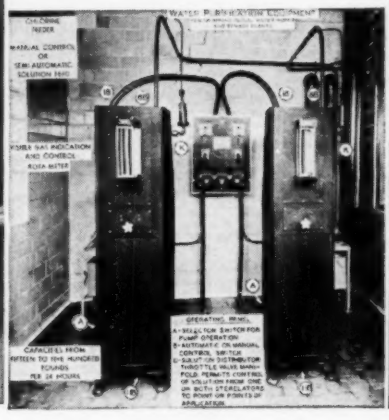

WATER PURIFICATION EQUIPMENT
CHLORINE FEEDER
MANUAL CONTROL OR SEMI-AUTOMATIC SOLUTION FEED
FIG. 1630 SCALE AND GAS TANK

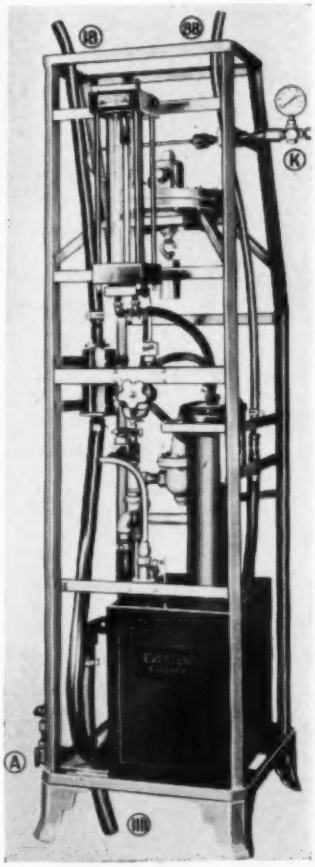
R-512X1
Showing weighing scale for chlorine gas



R514
Semi-automatic operation (with control panel)

WATER PURIFICATION EQUIPMENT
CHLORINE FEEDER
MANUAL CONTROL OR SEMI-AUTOMATIC SOLUTION FEED
VISIBLE INDICATING ROTA-METER PRECISELY ACCURATE
A—WATER SUPPLY INLET
K—GAS SUPPLY INLET
BOOSTER PUMP
USED WHERE HIGH BACK PRESSURE IS ENCOUNTERED OR WHERE ABSOLUTE SEPARATION OF POTABLE WATER OR SEWAGE IS DESIRED.

R515XX
Showing booster pump



R-486
SterElator without panel mountings

INSTALLATIONS—There is an accurate, safe and efficient EVERSON installation for every problem of water purification, whether for water supply system, swimming pool or sewage treatment. Hundreds of installations and 35 years of experience in every state and in foreign countries, have proven the safety and dependability built into this carefully designed equipment.

The STERELATOR is the basic unit for chlorine treatment. It is adaptable to a variety of controls to function in various ways:

VARIOUS CONTROLS

A MANUALLY CONTROLLED—The manually controlled, solution feed, vacuum type SterElator is the basic unit and is used where constant feed at a fixed rate is satisfactory. The rate of feed can be adjusted through a range of 10 to 1, 40 to 1 or 110 to 1, by the use of the chlorine control valve with the selected model to cover the capacity range desired. (For complete specifications send for Bulletin No. 2112.)

B SEMI-AUTOMATIC—By the addition of a solenoid operated water valve, the unit now becomes semi-automatic in its functions, starting and stopping with the pump whose pumpage is being chlorinated, always feeding chlorine gas at its set rate while operating. (For complete specifications send for Bulletin No. 2113.)

C CYCLE CONTROL—By using electronic timing devices, the basic unit may be adapted to intermittent operation for definite and adjustable cycles.

D HYDRO-MATIC—By adding a venturi tube or orifice plate to convert the rate of flow into differential pressure, and with an EVERSON Hydro-Matic proportioner, the basic unit will then automatically proportion the flow of gas to the flow of water being treated within a range of 5 to 1. (For complete specifications send for Bulletin No. 2114.)

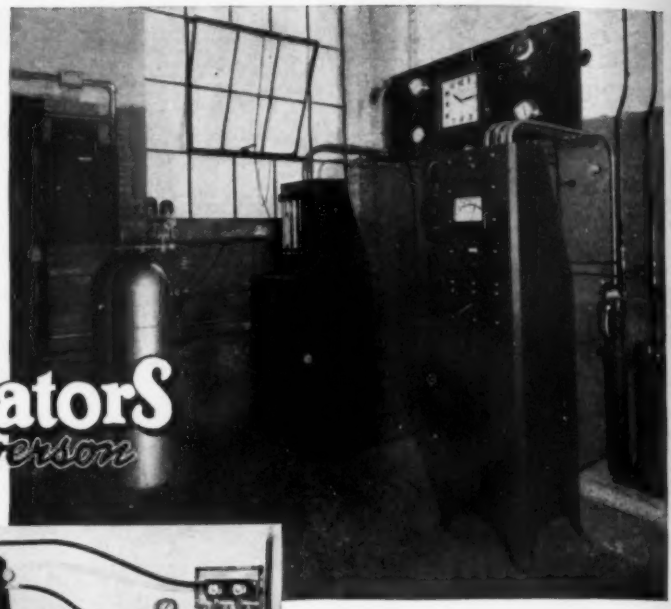
E ELECTRO-MATIC—By adding a venturi tube or orifice plate to convert the rate of water flow into a differential pressure to a Republic mercury well meter body which transmits the differential head measurements into a varying electrical resistance to a ROBOT containing electric controls, the basic unit will then automatically proportion the gas flow in direct proportion to the water flow within a range of 10 to 1. (For complete specifications send for Bulletin No. 2115.)

F TOTALIZING AND RECORDING METERS—If desired Totalizing and/or Graphic recording meters can be placed in this same meter circuit and graphically record and/or integrate the water flow.

G AIR-O-MATIC—By adding a venturi tube or orifice plate and a Republic pneumatic differential air transmitter, the SterElator unit will automatically proportion the gas flow in direct proportion to the water flow within a range of 10 to 1.

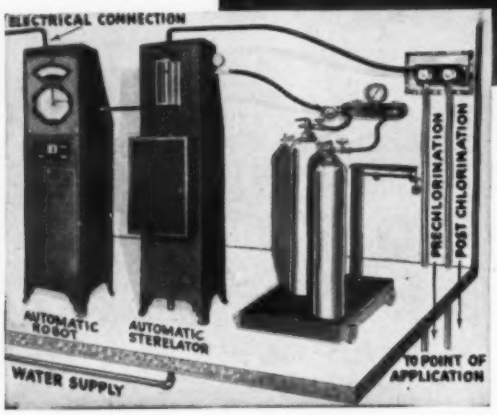
The EVERSON ROTA-METER indicates visibly the flow of chlorine gas, and with the highest accuracy. It also allows a much wider range in volume with one machine than any other type of chlorine meter. EVERSON has developed three types of application of the ROTA-METER: The *Standard*, the *Relay* and the *Duplex*, which make the SterElator flexible enough to meet any condition. The ratio between maximum and minimum metering capacity of each of the three types is:

STANDARD ROTA-METER	**10 to 1**
RELAY ROTA-METER	**40 to 1**
DUPLEX ROTA-METER	**100 to 1**

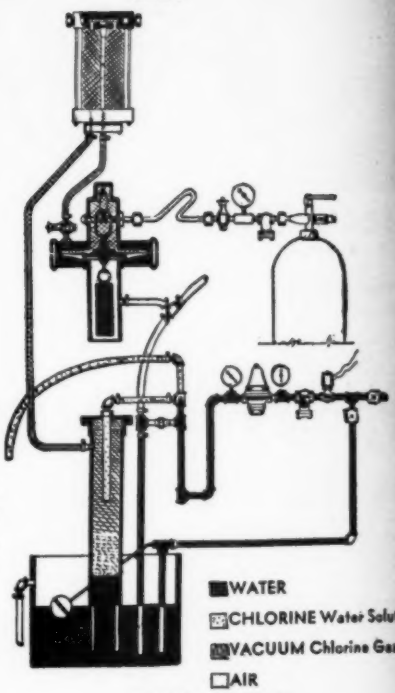


SterElators by Everson

R568-F



R-497

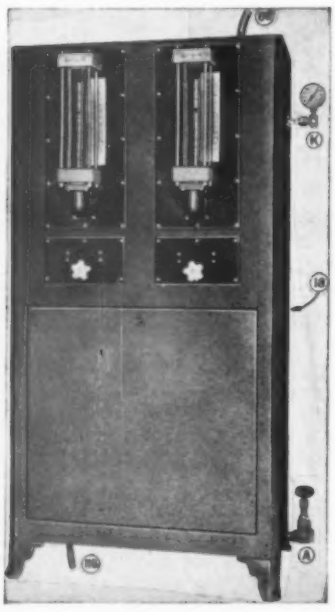


R489

FLOW DIAGRAM

AUTOMATIC SAFETY DEVICES

All EVERSON equipment is designed with automatic safety devices for every emergency. Besides the gas PRESSURE REGULATOR and SHUT-OFF VALVE, a vent to the outside is provided as an additional feature to allow any free gas within the absorption tower to escape. The Vacuum type valve or the hydraulically-operated valve (equipped with GRAVI-VAC attachment), shut off chlorine gas in cases of water failure, breakage of glassware, stoppage of the line, or any other circumstance which causes the vacuum to fail. Either of these devices insures that leakage will be *air-in* and not *chlorine-out*.



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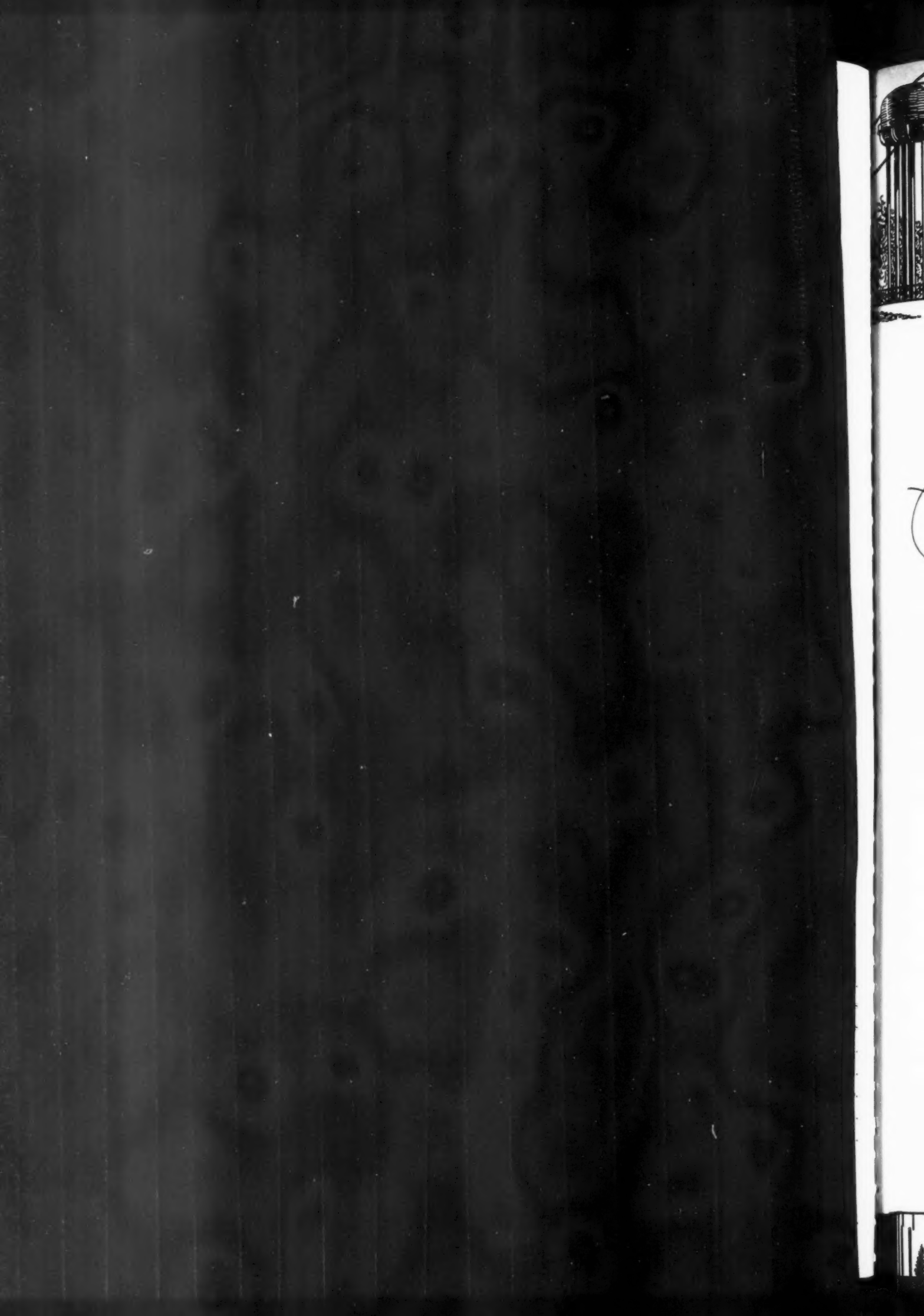

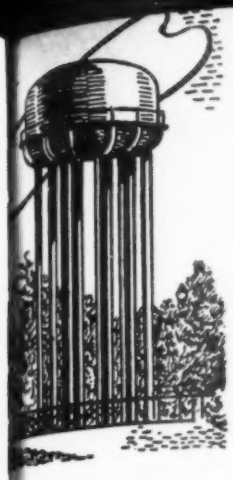

PART 1

WATER SUPPLY

WATER WORKS
& SEWERAGE

REFERENCE & DATA SECTION

1945

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AQUA NUCHAR has successfully controlled tastes and odors, some of which have been characterized as:

Earthy	Fishy
Woody	Marshy
Vegetable	Swampy
Bitter	Muddy
Aromatic	Chlorine

which may originate from decaying vegetation; Algae, such as synura, synedra, asterionella, uroglena, etc.; and Industrial trade wastes, such as phenols, solvent, volatile oils, etc.

AQUA NUCHAR is effective as a dechlorinating medium and is thus utilized where prochlorination or superchlorination is practiced.

Realizing that taste and odor troubles come suddenly in water plants, we have spotted stocks of AQUA NUCHAR at strategic points throughout the country in storage warehouses. You can feel assured that your order will receive immediate attention and you will be very agreeably surprised at the prompt service we can give you. Experts — from our Technical Service Department are available to study your taste and odor problems, no cost nor obligation.

The sterilization of water supplies by treatment with chlorine has been almost universally adopted as a means of rendering water safe for human consumption. With the development of the use of activated carbon in water works practice it is now possible to deliver a palatable as well as safe water to the consumers. THE COST OF TREATMENT IS MINOR WHEN IT IS CONSIDERED THAT WITH THE AVERAGE DOSAGES BEING APPLIED THE EXPENSE WORKS OUT TO ONLY THREE CENTS PER CAPITA PER YEAR.

"next to knowing - - - - is knowing where to find knowledge"

Foreword

We take especial pride, as publishers, in presenting this volume — The 1945 Reference and Data Number of WATER WORKS AND SEWERAGE

This section prepared by the Editor and Dr. George E. Symons, Associate Editor, with the aid of John C. Black, Managing Editor, presents the equivalent of a data handbook for designing engineers, managers, and operators of water works and sewerage systems.

The information contained herein has been carefully selected from past issues of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, considerable effort has been made to present the most economical and modern methods, and the latest tables and charts useful to water and sewage works operators and designers.

Even though supplied to subscribers at no charge beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Data Section as would be expected in a book devoted exclusively to the same type of material and published separately.

* * *

Note

Governmental restrictions on the use of paper makes it imposible to include as much material as we should like in this issue. In the past we have repeated useful basic data, tables, graphs, etc. — from year to year, chiefly for the benefit of new subscribers; certain other matter was repeated in alternate years; and new material was, of course, added. Thus the subscriber who kept two consecutive Reference and Data issues on file had all of the most important reference material published by Water Works and Sewerage.

None of the material contained in the 1944 issue is repeated in this issue. Instead, the new material is being augmented with certain basic material selected from the 1943 and earlier issues, with the intent of best serving all of our readers —especially the newer readers.

Nevertheless, in order to have a complete Reference and Data file it will be necessary for the readers to have available not only the current issue but also issues of the two years preceeding this issue. Therefore for the convenience of the user a consolidated four year index is being incorporated in this isue.

L. H. Enslow

Editor.

INDEX

FOR THE INDEX TO THE REFERENCE AND DATA MATERIAL, AND THE INDEX TO ADVERTISERS, SEE THE REAR OF THIS SECTION

CLASSIFIED INDEX of PRODUCTS

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Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Simplex Valve & Meter Co., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

BACK FILLERS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago 9, Ill.

BAR SCREENS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

BASIN CLEANERS
Champion Corp., Hammond, Ind.

BEARINGS, ROLLER & BALL
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 519 N. Holmes Ave., Indianapolis 6, Ind.

BELTS, SAFETY
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

BINS, STORAGE
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati, 16, Ohio.

BITUMINOUS COATINGS AND LININGS
(See also Cement Linings)
General Paint Corp., 3001 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

BLEACHING POWDER
Hood Chemical Co., 450 W. 31st St., New York City.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

BLOWERS, AIR (Centrifugal and Rotary)
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
De Laval Steam Turbine Co., Trenton, N. J.
General Electric Co., Schenectady, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

BLOWERS, GAS
(See Blowers, Air)

BLOWERS (Gasoline Engine Driven Portable)
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

BOILER FEED PUMP CONTROL
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Simplex Valve & Meter Co., 68th & Udland Sts., Philadelphia, Pa.

BOILER FEEDWATER TREATMENT AND EQUIPMENT
The American Well Works, Aurora, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron, Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., The, Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago 9, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

BOILER FURNACE, BRICK
Carborundum Co., Perth Amboy, N. J.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

BOILERS, GAS
American Radiator & Standard Sanitary Corp., Bessemer Bldg., burgh 30, Pa.

BOOKS, TECHNICAL
Theo. Audel & Co., 49 W. 23rd St., New York 10, N. Y.
John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

BRASS GOODS
(See also Pipe, Brass)
American Brass Co., Waterbury, Conn.
Bridgeport Brass, Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

BREATHING APPARATUS
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUTTERFLY VALVES
(See Valves, Butterfly)

CALCIUM HYPOCHLORITE
(See also Bleaching Powder)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

CALGON
(See Corrosion Suppression and Water Stabilization)

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Schramm, Inc., West Chester, Pa.

CARBON-ACTIVATED
(See Activated Carbon)

CARBONATORS (Recarbonation).
Carborundum Co., Perth Amboy, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Vogt Mfg. Co., Louisville, Ky.

CAR SPOTTERS & HAULAGE SYSTEMS
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Climax Engineering Co., Clinton, Iowa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Fort Pitt Steel Castings Div., H. K. Porter Co., McKeesport, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hunt, Rodney, Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe)

CATCH BASIN INLET
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

CATCH BASINS, CORRUGATED IRON
Armco Drainage Products Assn., Middletown, Ohio.

CATHODIC PROTECTIVE SYSTEMS
Dow Chemical Co., Midland, Mich.
Electro Rust-Proofing Co., 1026 Wayne Ave., Dayton, Ohio.
Johnston & Jennings Co., Rusta Restor Div., 877 Addison Rd., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

CAUSTIC SODA
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hood Chemical Co., 450 W. 31st St., New York City.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, 30 Rockefeller Plaza, New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., Empire State Bldg., New York 1, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT GUN
Cement Gun Co., Allentown, Pa.

CEMENT PIPE
(See Pipe, Cement; Pipe, Concrete)

CEMENT LINED PIPE
(See Pipe)

CEMENT LINING OF PIPE
Cement Lined Pipe Co., Lynn, Mass.
Centriline Corp., 140 Cedar St., New York City.
Tate Pipe Linings, Inc., Andover, Mass.

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL, CONVEYING EQUIPMENT
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.

Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold, 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION

Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Darco Corp., 60 E. 42nd St., New York City 17.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
The Dow Chem. Co., Midland, Mich.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hood Chemical Co., 450 W. 31st St., New York, N. Y.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York 17.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
L. A. Salomon & Bro., 216 Pearl St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHEMISTS AND ENGINEERS

(See Directory of Consultants, pages 116-117)

CHLORIDE OF LIME (Chlorinated Lime)

Hood Chemical Co., 450 W. 31st St., New York City.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

CHLORINATORS

(See also Hypochlorinators)
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., Sixth & Byrd, St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHLORINE DIOXIDE

(See Sodium Chlorite)

CHLORINE, LIQUID

Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Diamond Alkali Co., Pittsburgh, Pa.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

CHLORINE CONTROL EQUIPMENT

Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Food Machinery Corp., 3075 Twelfth St., Riverside, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CHUTES, COAL, ETC.

Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE

Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Co., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rennselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT

Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR

Carson-Cadillac Corp., Birmingham, Ala.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

CLARIFIERS, SEWAGE AND WATER

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

CLEANERS, AIR INTAKE

Burgess-Manning Co., 2815 W. Roscoe, Chicago, Ill.

CLAY PIPE

(See Vitrified Clay Pipe and Products)

CLEANING SEWER MAINS

Champion Corp., Hammond, Ind.
Flexible Sewer-Rod Eqpt. Co., 9050 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York 7, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CLEANING WATER MAINS

Flexible Underground Pipe Cleaning Co., 9050 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
Stuart Brumley Corp., Baltimore, Md.
Tate Pipe Linings, Inc., Andover, Mass.

COAGULANTS & COAGULATION CONTROL CHEMICALS

Activated Alum Corp., Curtis Bay, Baltimore, Md.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Stuart Brumley Corp., 316 N. Charles St., Baltimore 1, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COAL & ASHES HANDLING MACHINERY

(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD

Atlas Mineral Products Co., Mertztown, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

COATINGS AND LININGS

(See Bituminous Coatings and Linings)

COCKS, CURB, METER, CORPORATION, ETC.

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

COCKS, LUBRICATED PLUG

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.

COLLECTORS (Sludge)

The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Yeomans Bros., 1433 N. Dayton St., Chicago 22, Ill.

COMBUSTION INDICATORS AND RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., York 18, N. Y.

COMMINUTORS

(See Grinders also)
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, SEWER JOINT

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Co. Bldg., Philadelphia 2, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR

Clayton Mfg. Co., Alhambra, Calif.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.

Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machinery Corp., Harrison, New Jersey.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS
Gardner-Denver Co., Quincy, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

CONCRETE CONTROL
Scientific Concrete Service Corp., McLachlen Bldg., Washington, D. C.

CONCRETE HARDENER
Connelly Iron Sponge and Governor Co., 3154 So. California Ave., Chicago, Ill.
Diamond Alkali Co., Pittsburgh, Pa.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

CONCRETE PIPE
(See Pipe, Concrete.)
American Concrete Pipe Assn., 33 W. Grand Ave., Chicago 10, Ill.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.

CONDENSERS (Steam)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTRACTORS (Water Works & Sewerage)
Ambursen Engineering Corp., 295 Madison Ave., New York, N. Y.
Cement Gum Co., P. O. Box 424, Allentown, Pa.
Fritz Ziebarth, 820 W. Esther St., Long Beach, Calif.

CONTROLLERS, AUTOMATIC, ELECTRIC
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

CONVEYORS AND CONVEYING EQUIPMENT
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., Cleveland, Ohio.
Food Machinery Corp., 3075 Twelfth St., Riverside, Calif.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Omega Machine Co., 3409 E. 18th St., Kansas City, Mo.

COOLING TOWERS
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

COPPERS (Sulphate of Iron)
Innis-Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York 6, N. Y.
Innis-Speiden & Co., 117 Liberty St., New York City.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dow Chemical Co., Midland, Mich.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

COUPLINGS & CONNECTIONS, PIPE
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
A. M. Byers Co., Pittsburgh, Pa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
National Tube Co., Frick Bldg., Pittsburgh, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.

COUPLINGS, FLEXIBLE
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Dresser Mfg. Div., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 220 S. Belmont Ave., Indianapolis 6, Ind.
Lombard Governor Corp., Ashland, Mass.
Peerless Pump Division, Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.

COVERS, HANDHOLE, MANHOLE, SAMPLING
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
United Concrete Form Products Co., 5243 W. 25th Pl., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

CRANES & HOISTS
Hunt, Rodney, Machine Co., Orange, Mass.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

CULVERT CLEANERS
Champion Corp., Hammond, Ind.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

CULVERT PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
American Concrete Pipe Assn., 33 W. Grand Ave., Chicago, Ill.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron).
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

DECHLORINATING EQUIPMENT AND CHEMICALS
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DE-MINERALIZATION (Water)
Dorr Co., 570 Lexington Ave., New York 22, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DEMOLITION TOOLS
Gardner-Denver Co., Quincy, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

DIAPHRAGM, PUMP
Ralph B. Carter Co., 53 Park Pl., New York City.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
The Deming Company, Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Yeomans Bros., 1423 N. Dayton St., Chicago 22, Ill.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES & TUBES
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DIGESTERS EQUIPMENT (Sludge)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison St., Pittsburgh, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Filter)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

DRIVES, CHAIN
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DRIVES, RIGHT ANGLE GEAR
Johnson Gear Co., Berkeley, Calif.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
J. P. Devine Mfg. Co., Div. H. K. Porter Co., 49th and Harrison St., Pittsburgh, Pa.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.

EJECTORS, PNEUMATIC OR STEAM (For Sewage and Sludge)
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICALLY OPERATED GATE VALVES
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.

Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINEER TRAINING
Alexander Hamilton Institute, 71 W. 23rd St., New York 10, N. Y.

ENGINEERS AND CHEMISTS
(See Directory of Consultants, pages 116-117)

ENGINEER'S REPRODUCTION SERVICE
Lithoprint Co. of N. Y., 145 Hudson St., New York, N. Y.

ENGINE GENERATOR UNITS
Climax Engineering Co., Clinton, Iowa.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Northrop & Co., Inc., 50 Church St., New York 7, N. Y. (Gasoline Driven Portable.)
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, DIESEL
Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Schramm, Inc., West Chester, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES (Gas & Gasoline)
Buffalo Gasolene Motor Co., Buffalo 13, N. Y.
Climax Engineering Co., Clinton, Iowa.
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Le Roi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SLUDGE GAS
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Climax Engineering Co., Clinton, Iowa.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Vacuum Pump)

FANS, EXHAUST AND VENTILATING
Jeffrey Mfg. Co., The, 968-99 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 505, Troy, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FEED WATER HEATERS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED WATER TREATMENT
(See Boiler Feed Water Treatment.)

FERRIC CHLORIDE
Chem-Feeds, Inc., 77 Reservoir Ave., Providence, R. I.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York City.
Great Western Division, Dow Chemical Co., 310 Sansome St., San Francisco, Calif.
Hooker Electrochemical Co., Buffalo Ave. and Ward St., Niagara Falls, N. Y.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa. (Liquid.)
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC CHLORIDE FEEDERS
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

FERRIC SULFATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co. Merrimac Div., Boston, Mass.
L. A. Salomon & Bro. 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

FERROUS SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

FIBRE PIPE
(See Pipe, Fibre)

FILTER-AIDS
Anthracite Eqpt. Corp., 101 Park Ave., New York City.
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER CLEANING PROCESS
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Virginia Smelting Co., West Norfolk, Va.

FILTERING EQUIPMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
R. D. Cole Mfg. Co., Newnan, Ga.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Oliver United Filter, Inc., New York City.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machinery Corp., Harrison, N. J.

FILTER GRAVEL
(See Gravel, Filter)

FILTER PLATES AND TUBES
Carborundum Co., Perth Amboy, N. J
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER SAND
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Tamms Silica Co., 228-W8 N. La Salle St., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

FILTER UNDERDRAINS, SEWAGE
The American Well Works, Aurora, Ill.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

FILTER UNDERDRAINS, WATER
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

FILTER WASH CONTROL
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St., N.W., Washington, D. C.
Permutit Co., 330 W. 42nd St., York 18, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

FIRST AID KITS
Mine Safety Appliance Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
American Smelting and Refining Co., 120 Broadway, New York City.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

FITTINGS, TEES, ELLS, ETC.
American Cast Iron Pipe Co., Birmingham, Ala.
Bridgeport Brass Co., Bridgeport 2, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
The Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
M & H Valve & Fittings Co., anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
The American Well Works, Aurora, Ill.

Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart-Brumley Corp., 516 N. Charles St., Baltimore, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Merco Nordstrom Valve Co., Lexington Ave., Pittsburgh, Pa.
Renesselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW RECORDERS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

FLOW REGULATORS
American Meter Co., 60 E. 42nd St., New York City.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., So. Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Bros. Mfg. Co., 1402 W. Main St., Louisville 3, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FORMS AND FORM EQUIPMENT
Williams Form Engineering Corp., Box 925 Madison Square Station, Grand Rapids 7, Mich.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

GARBAGE GRINDERS
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
General Electric Co. (household), Bridgeport, Conn.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

GAS DIFFUSERS
The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS ENGINES
(See Engines, Gas & Gasoline)

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS HOLDER INSPECTION SERVICE
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS INDICATORS AND DETECTORS
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

GAS MASKS (Cannister and Hose)
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

GAS PUMPS
(See Pumps, Gas)

GAS PURIFICATION
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

GAS REGULATORS
(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, ROLLER
Hunt, Rodney, Machine Co., Orange, Mass.

GATES, SHEAR
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rennsselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

GATES, SLUICE
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate)

GAUGES (Liquid Level, Pressure Recording)
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y. (Pressure).
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago 3, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Wallace & Tiernan Co., Inc., Newark, N. J.

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
The Earle Gear & Machine Co., 4725 Stenton Ave., Philadelphia 44, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lombard Governor Corp., Ashland, Mass.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES
(See Engine Generating Sets)

GOOSENECKS
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church New York 7, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GRAVEL, FILTER
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

GREEN SAND (Zeolite)
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar New York 6, N. Y.

GRINDERS, SCREENINGS
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
H. K. Porter Co., Inc., 49th and Harrison Sts., Pittsburgh, Pa.

GRIT CHAMBER EQUIPMENT
The American Well Works, Aurora, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

GUNITING CONTRACTING
Cement Gun Co., P. O. Box 424, Allentown, Pa.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Pa.
Edson Corp., 49 D St., So. Boston, Mass.
Gardner-Denver Co., Quincy, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Schramm, Inc., West Chester, Pa.
Sullivan Machinery Co., Michigan City, Indiana.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRANTS (Fire)
The Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT
(See pH Test Equipment.)

HYPO-CHLORINATORS
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.

Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Morse Boulger Destructor Co., 205 E. 42nd St., New York City.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

INDICATOR POSTS
Eddy Valve Co., Waterford, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vogt Bros. Mfg. Co., 1402 W. Main St., Louisville 3, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

INSTRUMENTS (Surveying, Hydrographic and Navigation)
Leupold & Stevens Instruments, 4445 N. E. Glisan St., Portland 13, Oregon.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULPHATE
Innis, Speiden & Co., 117 Liberty St., New York City.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

JOINTING COMPOUND AND MATERIALS
Atlas Mineral Prod. Co., Mertztown, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
Rensselaer Valve Co., Troy, N. Y.
Servicised Products Corp., 6051 West 65th St., Chicago, Ill.

JOINT COMPOUND, SEALING
J. H. Grancell, 1601 E. Nadeau St., Los Angeles 1, Calif.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., N. Y., N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JOINTS, MECHANICAL, FLEXIBLE
American Cast Iron Pipe Co., Birmingham, Ala.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Victaulic Co. of America, 30 Rockefeller Plaza, New York, N. Y.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Northrup & Co., Inc., 50 Church St., New York 7, N. Y.

LABORATORY APPARATUS
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

LOCATORS, BOX, PIPE AND VALVE
(See Respective Headings.)

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

MAP REPRODUCTIONS
Lithoprint Co. of N. Y., 145 Hudson St., New York City.

MEASURING INSTRUMENTS
(See Instruments.)

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.
Badger Meter Co., Milwaukee, Wis.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Illinois.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Hays Mfg. Co., Erie, Pa.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS
American Meter Co., 60 E. 42nd St., New York City.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, PITOT
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
American Meter Co., 60 E. 42nd St., New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Worthington - Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Invanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
American Meter Co., 60 E. 42nd St. New York City.
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
National Meter Division of Pittsburgh Equitable Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington - Gamon Meter Co., Newark, N. J.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MILL SUPPLIES
Tucker Co., Inc., The, 75 Murray St., New York, N. Y.

MIXERS, CHEMICAL
The American Well Works, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St. New York 18, N. Y.
H. K. Porter Co., Inc., 1932 Oliver Bldg., Pittsburgh 22, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
H. K. Porter Co., Inc., 1932 Oliver Bldg., Pittsburgh 22, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Box 1122, Louisville 1, Ky.
Yeomans Brothers Equipment Co., 1433 N. Dayton St., Chicago 22, Ill.

MOTORS, ELECTRIC
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Star Electric Motor Co., Bloomfield, N. J.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

NIPPLES, PIPE
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
A. M. Byers Co., Pittsburgh, Pa.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.

Dresser Mfg. Co. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York, N. Y.

NO-OX-ID
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Bean-Cutler Div'n, Food Machinery Corp., 217 W. Julian St., San Jose 5, Calif.
Chain Belt Co., Milwaukee, Wis.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

ODOR & CARBON EVALUATION AIDS
American Norit Co., Jacksonville, Fla.
Darco Corp., 60 E. 42nd St., New York City 17.
Industrial Chemical Sales Div., West Va. Pulp & Paper Co., 230 Park Ave., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

OPERATING TABLES
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Rodney Hunt Machine Co., Orange, Mass.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

pH TEST EQUIPMENT
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
Northrop & Co., Inc., 50 Church St., New York, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

PIPE AND TANK COATINGS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE BENDING MACHINES
Hays Mfg. Co., Erie, Pa.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 4th Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Hunt, Rodney, Machine Co., Orange, Mass.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York City.
Centriline Corp., 140 Cedar St., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, CEMENT LINING OF
Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Tate Pipe Linings, Inc., 47 Haverhill St., Andover, Mass.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.

PIPE, COPPER, BRASS AND BRONZE
American Brass Co., Waterbury, Conn.
Bridgeport Brass Co., Bridgeport 2, Conn.
Hays Mfg. Co., Erie, Pa.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PIPE, CORRUGATED
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Ridge Tool Co., Elyria, Ohio.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE, DRILLS, JACKS AND PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE ENAMELS, PROTECTIVE —COAL TAR
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, FELT WRAPPING
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE, FIBRE
Fibre Conduit Co., Orangeburg, N. Y.

PIPE FITTINGS (See Fittings Pipe)

PIPE—GALVANIZED, LIGHT-WEIGHT (Quick Coupling, Transportable for Conveying Water)
Armco Drainage Products Assoc., Middletown, Ohio.
Champion Corp., Hammond, Ind.

PIPE, HARD RUBBER LINED
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

PIPE JOINT COMPOUNDS
(See Jointing Compounds.)

PIPE JOINTS (Mechanical)
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Carson-Cadillac Corp., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Hays Mfg. Co., Erie, Pa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.
R. D. Wood & Co., 400 Chestnut St., Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE JOINT TOOLS
Atlas Mineral Products Co., Mertztown, Pa.
Hays Mfg. Co., Erie, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

PIPE, LEAD LINED
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.

PIPE LOCATORS
Aqua Survey & Instrument Co., 1409 Marlowe Ave., Cincinnati, Ohio.
Frank N. Blake, North Adams, Mass.
S. F. Ferguson, 11 Hill St., Newark 2, N. J.
Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PIPE PUSHERS
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Am. Concrete Pipe Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete.)
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Clow and Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Fibre Conduit Co., Orangeburg, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., 111 W. Washington St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, STEEL
American Locomotive Co., Alco Products Div., 30 Church St., New York 8, N. Y.
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
American Cast Iron Pipe Co., Birmingham, Ala.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Johns-Manville, 22 East 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE TAPPING MACHINES
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

PIPE TEST PLUGS
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)
Ridge Tool Co., Elyria, Ohio.
Tucker Co., Inc., 75 Murray St., New York, N. Y.

PIPE, VITRIFIED CLAY
(See Vitrified Clay Pipe and Products.)

PIPE, WELDED STEEL
Armco Drainage & Metal Products, Inc., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
John Nooter Boiler Works Co., 1410 S. 2nd St., St. Louis, 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

PIPE, WRAPPING
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE, WROUGHT IRON
A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

PITOT TUBES
Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.

PNEUMATIC TOOLS
Schramm, Inc., Westchester, Pa.
Sullivan Mach. Co., Michigan City, Ind.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2336 Wolfram St., Chicago, Ill.

PRESSURE REGULATORS
American Meter Co., 60 E. 42nd St., New York City.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Clayton Mfg. Co., Alhambra, Calif.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
The Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

PROPORTIONING EQUIPMENT (Chemical)
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, O.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

PUMP PRIMERS
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, ACID-HANDLING
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton-Dowd Pumps, Peerless Pump Division, Inc., Quincy, Illinois.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, New York 18, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthing Pump & Mach. Corp., Harrison, N. J.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, BOILER FEED
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Division, Inc., Quincy, Illinois.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pump, Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, CELLAR DRAINER
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Division, Inc., Quincy, Ill.
The Deming Co., Salem, Ohio
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, CENTRIFUGAL
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
A. D. Cook Co., Inc., Lawrenceburg, Indiana.
Dayton - Dowd Pumps, Peerless Pump Division, Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio
Economy Pump Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., 50 Church St., New York 7, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th & Harrison Sts., Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
A. D. Cook Co., Inc., Lawrenceburg, Indiana.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D. St., South Boston, Mass.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Yeomans Brothers Co., 1433 Dayton St., Chicago 22, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.

PUMPS, HYDRAULIC
Ross Valve Mfg. Co. Inc., Troy, N. Y.

PUMPS, JETTING
Ralph B. Carter Co., 53 Park Pl., New York N. Y.
Gorman-Rupp Co., Mansfield, Ohio.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Ave. 26, Los Angeles 31, Calif.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., 1024 Weller Ave., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Station, Memphis 8, Tenn.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Div., H. K. Porter Co., 49th & Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING
Aurora Pump Co., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Gorman-Rupp Co., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Northrop & Co., 50 Church St., New York 7, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps, Inc., Hamilton, Ohio.
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Ageles 31, Calif.
Pomona Pump Co., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.

De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 18, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Economy Pumps Inc., Hamilton, Ohio
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., Mansfield, Ohio.
Lombard Governor Corp., Ashland, Mass.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div., H. K. Porter Co., 49th & Harrison Sts., Pittsburgh, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE
The American Well Works, Aurora, Ill.
Aurora Pump Co., Aurora, Ill.
A. D. Cook, Inc., Lawrenceburg, Indiana.
Dayton - Dowd Pumps, Peerless Pump Div., Inc., Quincy, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
The Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Morris Machine Works, Baldwinsville, N. Y.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
Pomona Pump Co., 206 E. Commercial St., Pomona, Calif.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, VACUUM
Allen-Billmyre Corp., 449 Fayette Ave., Mamaroneck, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps Inc., Hamilton, Ohio.
Oliver United Filters Inc., 33 W. 42nd St., New York 18, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

RATE OF FLOW CONTROLLERS
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Place., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

RATE OF FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Northrop & Co., 50 Church St., New York 7, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS
Mueller Co., Decatur, Ill.
Ridge Tool Co., Elyria, Ohio.

RECARBONATORS
The American Well Works, Aurora, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Vogt Mfg. Co., Louisville, Ky.

RECEIVING COIL, AMPLIFYING
Frank N. Blake, 15 Highland Ave., North Adams, Mass.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, SEWAGE
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS, PRESSURE (Water and Gas)
American Meter Co., 60 E. 42nd St., New York City.
American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

RESPIRATORS
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

ROBOT FILTER AND SOFTENER OPERATORS
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUBBER LINED PIPE AND VALVES
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

RUST PREVENTION (Tanks, Pipe Lines, Submerged Metal)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Dow Chemical Co., Midland, Mich.
Electro Rust-Proofing Corp., 1026 Wayne Ave., Dayton 10, Ohio. (Cathodic Protection)
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia, Pa.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

SADDLES, PIPE
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

SAFETY EQUIPMENT (For Workers)
Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.

SAMPLERS AND SAMPLING TABLES
Chem - Feeds - Inc., 77 Reservoir Ave., Providence, R. I.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., 422 First Ave., Pittsburgh, Pa.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SAND EXPANSION INDICATORS
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

SCALE PREVENTION CHEMICALS
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave, Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

SCALES, SLUDGE CONVEYOR
Builders-Providence, 9 Codding St., Providence, R. I.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.

SCALES, WEIGHING
Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.

SCREENS, INTAKE
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago 9, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SCREENS, SAND, GRAVEL AND STONE
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Rodney Hunt Machine Co., Orange, Mass.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SCREENS, VIBRATING
Link Belt Co., 307 N. Michigan Ave., Chicago 1, Illinois.

SCREENS, WATER WELL
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)
Nat'l Clay Pipe Mfrs. Inc., 111 W. Washington St., Chicago, Ill.

SEPTIC TANKS (Vitrified Clay)
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

SERVICE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
United Concrete Form Products Co., 5243 W. 25th Place, Chicago, Ill.

SEWAGE EJECTORS
(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SEWAGE SCREENING GRINDERS
(See Grinders, Screenings)

SEWAGE SLUDGE INCINERATOR
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Morse Boulger Destructor Co., 216 East 45th St., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWER CLEANERS
J. C. Fitzgerald, P. O. Box 289, Coral Gables 34, Fla.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

SEWER PIPE
(See Pipe, Sewer)

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.

Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER PIPE LOCATORS
Frank N. Blake, North Adams, Mass.

SEWER RODS
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.

SHEETING
American Brass Co., Waterbury, Conn., (Copper and Copper Alloys).
Armco Drainage Products Assn., Middletown, Ohio (Iron & Steel).
Bridgeport Brass Co., Bridgeport 2, Conn. (Copper and Copper Alloys).
Johns-Manville Co., 22 E. 40th St., New York 16, N. Y. (Asbestos).

SIGHT FEEDERS (For Chemical Pumps)
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

SILENCERS, ENGINE, INTAKE, EXHAUST AND AIR INTAKE
Burgess-Manning Co., 2815 W. Roscoe, Chicago, Ill.

SIPHONS (Sewage)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City. (Alternating.)
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SLEEVES, PIPE REPAIR
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Dresser Mfg. Div., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (Valve)
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg., Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS
(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

SLUDGE GAS ENGINES
(See Engines, Sludge Gas)

SLUDGE PUMPS
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Morris Machine Works, Baldwinsville, N. Y.
Oliver United Filters, Inc., 33 W. 42nd St., New York 18, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Quimby Pump Co., Div. H. K. Porter Co., 49th and Harrison Sts., Pittsburgh, Pa.
Worthington Pump & Machinery Corp., Harrison, N. J.
Yeomans Brothers Co., 1433 N. Dayton St., Chicago 22, Ill.

SNUBBERS
(See Silencers.)

SODA ASH
Diamond Alkali Co., Pittsburgh, Pa.
Hood Chemical Co., 450 W. 31st St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE
Dearborn Chemical Co., 310 Michigan Ave., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.

SODIUM BISULPHITE
General Chemical Co., 40 Rector St., New York, N. Y.

SODIUM CHLORITE
Mathieson Alkali Works, 60 East 42nd St., New York 17, N. Y.

SODIUM PHOSPHATES (Glassy)
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.

SODIUM SILICATE
Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Philadelphia Quartz Co., Third & Ionic Sts., Philadelphia 6, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS (See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION
De Laval Steam Turbine Co., Trenton, N. J.
The Earle Gear & Machine Co., 4725 Stenton Ave., Philadelphia 44, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPRINKLING FILTERS (Sewage)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS
(See Filter Underdrains, Sewage.)

STACKS
Cement Gun Co., P. O. Box 424, Allentown, Pa.
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment, 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

STACKS, FUME
Johns-Manville, 22 E. 40th St., New York City.

STANDPIPES
(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION
(See Cathodic Protection Process.)

STERILIZING WATER MAINS
(See Water Main Sterilization)

STIRRERS (Laboratory)
Dorr Co., 570 Lexington Ave., New York City.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Omega Mach. Co., Inc., 9 Codding St., Providence 1, R. I.
Phipps & Bird, Inc., Sixth & Byrd Sts., Richmond, Va.
H. K. Porter Co., Inc., 1932 Oliver Bldg., Pittsburgh 22, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

STOKERS
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

STORAGE TANKS (See Standpipes and Tanks)

STRAINERS, SUCTION
Barrett, Haentjens & Co., Hazleton, Pa.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA
(See Filter Alum)

SULPHUR DIOXIDE (Liquid)
Great Western Div., Dow Chemical Co., 310 Sansome St. San Francisco, Calif.
Virginia Smelting Co., West Norfolk, Va.

SUPERNATANT LIQUOR (Selectors and Treaters)
Pacific Flush-Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SWIMMING POOL EQUIPMENT
Ralph B. Carter Co., 53 Park Pl., New York City.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Josam Mfg. Co., 1783 East 11th St., Cleveland, Ohio.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.
Yeoman Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SWITCHBOARDS
Climax Engineering Co., Clinton, Iowa.
Johns-Manville, 22 East 40th St., New York, N. Y.
Westinghouse Electric & Mfg. Co., P. O. Box 868, Pittsburgh 30, Pa.

TANKS AND STANDPIPES (Concrete)
Cement Gun Co., Inc., P. O. Box 424, Allentown, Pa.

TANKS AND STANDPIPES (Steel)
Chicago Bridge & Iron Co., 2198 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
H. K. Porter Co., 49th & Harrison, Pittsburgh, Pa.
The Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.

TANKS, PLASTIC LINED
Proportioneers, 9 Codding St., Providence 1, R. I.

TANKS, RUBBER LINED
Atlas Mineral Products Co., Mertztown, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Nooter, John, Boiler Works Co., 1410 S. 2nd St., St. Louis 4, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Stacey Bros. Gas Construction Co., 5535 Vine St., Cincinnati 16, Ohio.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

TAPPING MACHINES
Hays Mfg. Co., Erie, Pa.
Mueller Co., Decatur, Ill.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

TASTE & ODOR REMOVAL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Norit Co., Jacksonville, Fla.
Cliffs Dow Chemical Co., Marquette, Mich.
Darco Corp., 60 E. 42nd St., New York 17, N. Y.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Tank & Mfg. Co., East Chicago, Ind.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
L. A. Salomon & Bros., 216 Pearl St., New York City.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Virginia Smelting Co., West Norfolk, Va.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

TESTERS (Water Meter)
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., E and 2nd Sts., South Boston 27, Mass.

National Meter Division of Pittsburgh Equitable Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Worthington-Gamon Meter Co., Newark, N. J.

THICKENERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., P. O. Box 300, Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

TOOLS, PIPE
(See Pipe Tools.)

TOOLS, PNEUMATIC
Schramm, Inc., Westchester, Pa.
Sullivan Machinery Co., Michigan City, Ind.

TRAPS, DRIP, FLAME, SEDIMENT
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

TRICKLING FILTER UNDERDRAINS
(See Filter Underdrains.)

TRICKLING FILTERS (High Rate, High Capacity)
The American Well Works, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Co., 222 West Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

TRITURATORS
(See also Grinders)
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES
Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING
Jeffrey Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC
De Laval Steam Turbine Co., Trenton, N. J.
Hunt, Rodney, Machine Co., Orange, Mass.
Morris Machine Works, Baldwinsville, N. Y.
S. Morgan Smith Co., York, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.

TURBINES, STEAM
De Laval Steam Turbine Co., Trenton, N. J.
Morris Machine Works, Baldwinsville, N. Y.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Chapman Valve Mfg., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE BOX LOCATORS
S. F. Ferguson, 11 Hill St., Newark, N. J.
Northrop & Co., Inc., 50 Church St., New York City.

VALVE OPERATOR
(See Gate Valve Operator)

VALVES
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange Mass.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Lombard Governor Corp., Ashland, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Roots-Connersville Blower Corp., Connersville, Ind.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, BUTTERFLY
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Hunt, Rodney, Machine Co., Orange, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.

VALVES, CHECK
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hersey Mfg. Co., E and First Sts., South Boston 21, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Northrup & Co., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

VALVES, CONE
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ross Valve Mfg. Co., Troy, N. Y.

VALVES, FLAP
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clow & Sons, James B., 201 N. Talman Ave., Chicago, Ill.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
Ludlow Valve Mfg., Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Northrup & Co., 50 Church St., New York 7, N. Y.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
The Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, LUBRICATED PLUG
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Merco-Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.

VALVES, MOTOR OPERATED
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hunt, Rodney, Machine Co., Orange, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
The A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Rodney Hunt Machine Co., Orange Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
National Machine Works, 1559 N. Sheffield Ave., Chicago, Ill.
Peerless Pump Div., Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Rensselaer Valve Co., Troy, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div. Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Connelly Iron Sponge and Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hagan Corp., Hagan Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RELIEF
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hays Mfg. Co., Erie, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Johnston & Jennings Co., 877 Addison Rd., Cleveland, Ohio.
Lombard Governor Corp., Ashland, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

VALVES, RUBBER, GLASS AND LEAD LINED
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Automatic Control Div., Climax Industries, 1949 S. Western Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Johns-Manville, 22 E. 40th St., New York, N. Y.
S. Morgan Smith, York, Pa.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)
Anderson Valve Corp., Oliver Bldg., Pittsburgh, Pa.
Barrett, Haentjens & Co., Hazleton, Pa.
Clayton Mfg. Co., Alhambra, Calif.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS
The Earle Gear & Machine Co., 4725 Stenton Ave., Philadelphia 44, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Lombard Governor Corp., Ashland, Mass.
Omega Machine Co., 9 Codding St., Providence 1, R. I.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St. Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATING SCREENS (Liquid)
Link Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.

VIBRATORS, ELECTRO-MAGNETIC
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VICES, PIPE
Ridge Tool Co., Elyria, Ohio.

VITRIFIED CLAY PIPE AND PRODUCTS
Nat'l Clay Pipe Mfrs., Inc., 111 W. Washington St., Chicago, Ill.

WASTE GAS BURNERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Chemlab Specialties Co., 52 Alvarado Road, Berkeley, Calif.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Hellige Inc., 3718 Northern Blvd., Long Island City, N. Y.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., Sixth & Byrd, Richmond, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark 1, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.

WATER HAMMER ARRESTERS
Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio.
S. Morgan Smith Co., York, Pa.

WATER MAIN STERILIZATION (A Service)
Luther & Wood, 310 Chandler Bldg., 1427 Eye St., N. W., Washington, D. C.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark 1, N. J.

WATER LEAK, LOCATING INSTRUMENTS
S. F. Ferguson, 11 Hill St., Newark 2, N. J.
Fisher Research Lab., 1961-63-65 University Ave., Palo Alto, Calif.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

WATER MAIN CLEANING
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York 7, N. Y.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Paint Corp., Cleveland, O.
Johns-Manville, 22 E. 40th St., New York City.
Reilly Tar & Chem. Corp., Merchants Bank Bldg., Indianapolis.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.

WATER SOFTENING CHEMICALS AND COMPOUNDS
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Luther & Wood, 1427 Eye St. N.W., Washington, D. C.
Mathieson Alkali Works, 60 East 42nd St., New York City.
National Aluminate Corp., 6221 W. 66 Place, Chicago, Ill.
Omega Machine Co., 9 Codding St., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Grant Bldg., Pittsburgh 19, Pa.
Stuart Brumley Corp., Baltimore, Md.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER SOFTENING EQUIPMENT
The American Well Works, Aurora, Ill.
Builders-Providence, Inc., 9 Codding St., Providence, R. I.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chem-Feeds-Inc., 77 Reservoir Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
F. B. Leopold Co., Inc., 422 First Ave., Pittsburgh, Pa.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Nooter, John, Boiler Works Co., 1410 2nd St., St. Louis 4, Mo.
Omega Machine Co., 3409 E. 18th, Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 204 Clinton St., Buffalo, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER STABILIZATION
The American Well Works, Aurora, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
C. T. McFarland Co., 523 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Vogt Mfg. Co., Louisville, Ky.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER SUPPLY CONTRACTORS
Ambursen Eng. Corp., 295 Madison Ave., New York, N. Y.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

WATER TREATMENT FOR SCALE AND CORROSION
Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
National Aluminate Corp., 6221 W. 66th Place, Chicago, Ill.
The Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Stuart Brumley Corp., 516 N. Charles St., Baltimore 1, Md.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER TREATMENT PLANTS (Steel)
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

WATER WASTE SURVEYS
S. F. Ferguson, 11 Hill St., Newark 2, N. J.
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

WEATHERPROOF PAINTS, ROOF COATINGS
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Reilly Tar & Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind.

WELLS, COMPLETE
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET
Dresser Mfg. Co., Bradford, Pa.

WROUGHT IRON (Pipe, Gates, Bars, Etc.)
A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

ZEOLITE AND ZEOLITE SOFTENERS
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Lakeside Engrg. Corp., 222 West Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Turbine Equipment Co., 75 West St., New York 6, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

MUNICIPAL DEPRECIATION ACCOUNTING PRACTICES

By N. T. VEATCH
Black & Veatch, Engineers, Kansas City, Mo.

THERE is a wide diversity in accounting practice among municipal water utilities. Most, if not all, privately owned water properties are under the jurisdiction of state regulatory bodies and follow accounting practices prescribed by such authorities.

There is little uniformity among water departments in regard to the use of a standard accounting system such as that prescribed by the National Association of Railroad and Utilities Commissioners or as suggested in the Manual of Water Works Accounting, published by the Municipal Finance Officers Association and the AWWA. The same lack of uniformity exists in regard to the handling of annual retirement or depreciation charges, and the creation of a retirement or depreciation reserve.

Depreciation losses are of such great importance in determining cost of service, adequacy of rates, etc., that it was decided to make an attempt to ascertain, as nearly as possible, how depreciation is being handled in present-day accounting practice among municipal water utilities. A questionnaire was sent out to some 275 cities, and 145 (or slightly over 52.5 per cent) were returned with pertinent information. This is believed to be a very satisfactory response, particularly now when time is invaluable and some research may be required to answer them. The information obtained is enlightening. The following table shows the number of cities reporting for several ranges in population.

Population	No. Reporting
Under 25,000	43
25,000 to 50,000	35
50,000 to 100,000	26
100,000 to 150,000	11
150,000 to 200,000	7
200,000 to 300,000	7
300,000 to 400,000	6
400,000 to 500,000	2
500,000 to 750,000	3
750,000 to 1,000,000	3
Over 1,000,000	2
Total	145

The geographical distribution of the 145 cities reporting is shown in the following list:

State	No. Reporting	State	No. Reporting
Arizona	1	Nebraska	5
Arkansas	1	New Hampshire	2
California	9	New Jersey	4
Colorado	4	New York	4
Connecticut	2	North Carolina	1
Florida	4	North Dakota	3
Idaho	2	Ohio	3
Illinois	7	Oklahoma	3
Indiana	2	Oregon	2
Iowa	7	Pennsylvania	2
Kansas	8	South Carolina	2
Kentucky	2	South Dakota	1
Louisiana	1	Tennessee	4
Maine	2	Texas	7
Maryland	2	Utah	1
Massachusetts	4	Virginia	3
Michigan	7	Washington	4
Minnesota	4	West Virginia	1
Mississippi	1	Wisconsin	10
Missouri	6	Wyoming	1
Montana	4		

The information received is representative geographically, but to a lesser extent as to the size-range of cities, because of lack of specific reports from the smaller municipalities. The data can, however, be considered as representative of average practice in the larger cities of the country.

The questions asked in the questionnaire were:

1. Do you make an annual charge to operations for retirements (annual depreciation charge)?
2. If so, how is amount determined?
3. What is the book value of depreciable property in your system? (Total of physical property exclusive of land.)
4. What is amount set aside each year for retirement or depreciation?
5. What is the present balance in your retirement or depreciation reserve account?
6. Do you carry an actual cash reserve for retirements or depreciation, or do you carry merely a book figure, the money being used for plant extensions?
7. Do you keep books in accordance with any standard system of accounts such as that outlined in the AWWA Manual of Water Works Accounting or that of the National Association of Railroad and Utilities Commissioners? Name?
8. Have you ever had your system appraised to determine its actual cost and the total amount of accrued depreciation existing in the system?

Replies

Answers to question No. 1 show that out of the 145 cities reporting, 107, or 73.8 per cent, make an annual charge to operations for depreciation.

Answers to question No. 2 indicate that approximately 70, or 65 per cent of the 107 cities making such annual charges for retirement or depreciation, calculated the amount by applying an annual percentage rate to the total book figures for each of the major accounts or like groups of property. The other 37 cities used various methods, some applying a fixed percentage to the entire capital account shown in the books, while others applied it to the depreciable property portion of the total capital account only. Some of the cities use a flat figure annually, the amount varying in some cases from year to year. Others used some modification of the different methods mentioned above.

Twenty-five cities out of a total of 70 cities that apply an annual rate to major accounts reported the annual rates used. These are summarized as follows:

PERCENTAGES USED IN DETERMINING ANNUAL ALLOWANCE FOR RETIREMENT OR DEPRECIATION

Class of Property	Percentage Annual Allowance for Depreciation: Minimum	Maximum	Average
Structures:			
Buildings	1.33	3.0	1.98
Dams and tunnels, etc.	0.80	1.0	0.90
Wells	3.00	7.0	3.94
Pumping equipment	2.00	10.0	4.37
Mains—cast-iron	0.67	2.0	1.29
Valves	1.00	2.0	1.52
Services	1.50	6.5	3.21
Meters	2.00	10.0	4.21
Hydrants	1.33	5.0	1.99
Furniture and fixtures	3.00	10.0	7.61
Transportation equipment	10.00	25.0	17.60

The percentages listed above were probably determined by several different methods, but the amounts indicate a mixture of sinking-fund and straight-line rates, the latter being more predominant. The average composite annual rate, expressed as a percentage of depreciable property for 100 of the 107 cities making annual allowances for depreciation, was approximately 1.77 per cent per year. This is, generally speaking, higher than composite rates allowed by regulatory commissions in determination of rates for private companies. As the above rate of 1.77 per cent is a weighted average of all of the 97 cities, inference should not be made that all of the rates applied are too high. As a matter of fact, all data obtained from this survey should be considered as average mass data, and indicating only the general and average situation, and should be applied to individual cases only on that basis.

Answers to question No. 3, in regard to book value of depreciable plant, show that the total book value of depreciable property in all of the 107 cities maintaining a depreciation reserve and making annual allowances for retirement or depreciation, is $1,047,000,000. This represents 77.8 per cent of the value of depreciable property in all of the 145 cities reporting, which amounts to $1,346,000,000. The total book value of depreciable property in cities where no reserve is maintained for retirement or depreciation is $299,600,000, or 22.2 per cent of the total in the 145 cities.

Per Capita Book Value

The population in the 107 cities which maintain retirement or depreciation reserves was, as of 1940, 13,986,182, or 76.1 per cent of the total for all 145 cities of 18,383,826. The average per capita book value of depreciable property in these cities is approximately $75. The population of the 38 cities in which no retirement or depreciation reserve is carried on the book was 4,397,644, or 23.9 per cent of the total population of all the cities reporting. The average per capita book value of depreciable property in this group of cities is approximately $68.

The reasons for the difference in per capita book value of the two groups of cities is not clear but may be due to a greater cost of supply works in the larger group and to some extent to the accounting practice of both groups. The above figures indicate clearly that the data obtained in the survey are influenced by practice in the larger cities. The recognition of the need for making charges for retirement or depreciation, and creating a

reserve for that purpose, would be even less general in the smaller cities, which make up the majority of the total number of water utilities in the country, than in the larger ones represented in this survey.

Answers to question No. 4, regarding the amount set aside each year for retirement or depreciation, totaled for 97 of the 107 cities reporting such charges, $17,747,607, or 1.77 per cent of the total book value of depreciable property in the same cities. This percentage (1.77 per cent) represents the average of all 97 cities, and many of them have individual annual allowances much higher. As a matter of fact, the composite figure of 1.77 per cent is considerably higher than the composite percentage used in a number of cities which are following schedules recommended by their state regulatory body.

Answers to question No. 5, in regard to the amount of balances in the retirement or depreciation reserve, show that the total of all balances for 100 of the 107 cities having such balances is $254,297,972, or 27 per cent of the total book value of depreciable property in those cities. The retirement or depreciation reserve of 27 per cent indicates unnecessarily large reserves, a subject which will be discussed later.

Answers to question No. 6, regarding the character of the reserve, i.e., whether merely a book figure, the cash being used for extensions or debt retirement, or whether an actual cash reserve, show that of the 107 cities reporting, 16 cities carry the reserve as cash, 87 cities carry the reserve as a book figure and 4 cities do not state how the reserve is handled. Approximately 84.5 per cent of those cities reporting an annual retirement of depreciation allowance carry only a book figure for the reserve, the money being used for replacements and extensions or for debt retirement.

Among the 107 cities carrying a retirement or depreciation reserve, there are three commonly used methods in which accounting for depreciation is shown on the balance sheet. These methods are:

1. The inclusion of the total capital investment in the property as an asset, the liability due to accrued depreciation being shown as a reserve for depreciation under liabilities.
2. The inclusion of the total capital investment in the property as a sub-total under assets from which is deducted the accumulated reserve for depreciation, the net remaining capital investment then appearing as a net asset in the total assets.
3. The inclusion as a net asset of the net remaining capital investment after depreciation as of the date of the balance sheet, no reference being made to the accrued amount or annual rate for depreciation.

Methods 1 and 2 give a complete and true statement of the financial position of the property so far as physical plant and the reserve are concerned. Method 3 does not show a complete record of physical plant costs and in case the accruals to the reserve (deductions from capital investment) are either too small or too large, the statement of plant account is also respectively too large or too small. The plant account should be corrected annually to reflect actual additions and retirements, and not be influenced in total by the retirement or depreciation reserve. The determination of the adequacy to the reserve will be discussed later in this paper.

Answers to question No. 7, regarding system of accounts used, indicate that 90 out of the 145 cities reporting, or 62 per cent, are using some standard bookkeeping system such as that prescribed by the NARUC, the Manual of Water Works Accounting or by their respective state regulatory bodies. Certain others are using some modification of some of the above mentioned systems, set up by their accountants or auditors.

Lack of Uniformity

It is apparent that there is a decided lack of uniformity in accounting practices in the 145 cities reporting and that it would be desirable to have all water utility properties operated at least reasonably close to some standard uniform system of accounts. Unless some uniform system of accounting is adhered to, it is impossible to make an intelligent comparison of costs and other statistical data involved in the accounting.

Since a majority of the cities that are following some standard uniform system of accounting are using that of the NARUC, for adaptations thereof by state regulatory bodies, it would seem that this would be a good system for cities to adopt if a change is made. The use of an expert accountant versed in utility accounting is always desirable, particularly in setting up a system of accounts.

Answers to question No. 8 show that 52 of the 145 cities reporting, or approximately 36 per cent, have had appraisals made of their property. The greater part of these had been made at the time of acquisition. Very few appraisals or determinations of the actual accrued depreciation existing in the respective systems had been made in the last 10 years.

The information obtained from the survey covered in the preceding paragraphs is summarized in Table I.

Before analyzing the facts disclosed from the survey in regard to the adequacy of annual allowances and reserves for retirement or depreciation, it would be well to review the definition of depreciation and the reasons for accounting for it.

Depreciation has been defined as "the loss in service value not restored by current maintenance." Among the general causes to be given consideration are wear and tear, decay, action of the elements, inadequacy, obsolescence, changes in the art, changes in the demand and requirements of public authorities. The combined effect of such causes is called depreciation.

Summary of Data Obtained from Survey

		Pct. of Total
(1) Cities making annual charge for retirement or depreciation and having a reserve	107	73.8
(2) Cities not making annual charge for retirement or depreciation and not having a reserve	38	26.2
Total number of cities reporting	145	100.0
Total number of states represented	41	85.4
Total book value depreciable property in (1) above (107 cities)	$1,047,000,000	77.8
Total book value depreciable property in (2) above (38 cities)	$ 299,600,000	22.2
Total book value depreciable property in all cities reporting (145 cities)	$1,346,600,000	100.0
Population (1940) of cities in (1) above	13,986,182	76.1
Population (1940) of cities in (2) above	4,397,644	23.9
Total population (1940) of all cities reporting (145 cities)	18,383,826	100.0
Total amount of retirement or depreciation reserve in (1) above (includes 100 out of 107 cities)	$ 254,297,972	
Ratio of reserve to depreciable property in (1) above (includes 100 out of 107 cities) *percentage*	27	
Total amount of annual allowance for retirement or depreciation in (1) above (includes 97 out of 107 cities)	$ 17,747,607	
Ratio of total annual allowance to total depreciable property in (1) above (includes 97 out of 107 cities) *percentage*	1.77	
Percentage of (1) (107 cities) basing annual retirement or depreciation allowance upon percentages applied to major accounts or like groups of property	65	
Percentage of (1) (107 cities) carrying retirement or depreciation reserve as book figure only	84.5	
Percentage of (1) above (107 cities) carrying cash retirement or depreciation reserve	15.5	
Percentage of (1) above (107 cities) using some standard system of uniform accounting	62.0	
Percentage of total cities reporting (145 cities) having had systems appraised	36.0	

Causes of Depreciation

The general causes of depreciation have been logically classified into two general groups by Marston and Agg.* This classification as given by the above authority is:

(1) Physical Causes—
  (a) Sudden physical damage, due to
    1. Miscellaneous accidents
    2. Disasters
  (b) Physical decrepitude, due to
    1. Physical deterioration, due to action of the elements, etc.
    2. Wear and tear
(2) Functional Causes—
  (a) Functional inefficiency, due to
    1. Inadequacy
    2. Obsoleteness
    3. Supersession

The division of causes of retirement into physical and functional is a natural one, as the service life of any unit of property may be, and usually is, determined by one independently of the other.

Depreciation is generally recognized as an increment of cost in all commercial business where physical property is involved. In the utility field, physical property constitutes a major part of the investment required to produce and distribute the commodity sold or the service rendered; therefore, it is especially important that the matter of depreciation be considered in the accounting connected with such enterprises.

The cost of service in any utility includes, among other things, materials used up in service. These materials include not only fuel, such as coal, oil or gas, but also physical property such as pumping stations, distribution mains, etc., the cost of which includes an increment of labor required to place them in service.

*Marston, Anson & Agg, Thomas R. Engineering Valuation. McGraw-Hill Book Co., Inc., New York and London (1936).

In the case of the fuels mentioned, it is easy to get the actual cost of the material used up in service, and very properly such costs are included in routine operating expenses.

The value of physical property such as that involved in pumping stations, pumping equipment, distribution mains, etc., is used up in service just as the fuels mentioned, although their consumption takes place over much longer periods, individual items having different lengths of service lives. Nevertheless, the portion of the service value of such items used up in service each year should be charged to operating expenses and made an increment of the cost of the commodity furnished, which is water in the example under consideration. This can only be done by accounting for depreciation. The setting up on the balance sheet of a reserve for the accrued depreciation existing in the property is in accord with the method of double-entry bookkeeping on the accrual basis which gives a complete and true picture of the financial position of the utility.

That depreciation takes place is a matter of common knowledge. It seems also as apparent that it should be considered as part of the cost of service, and that such increment of the total cost should be reflected in rates charged for the commodity sold. It has been and now is so considered by courts and commissions in the regulation of rates, and it is surprising that such a large number of cities do not consider the item of depreciation as an element of operating costs.

Plan for Depreciation

It is frequently stated that a city that is retiring its indebtedness does not need to take account of depreciation. There is enough apparent justification for such a statement to make it seem reasonable, although the premise is illogical. Assuming the money used for debt retirements comes from revenue, and that the annual amount of such retirements equals or exceeds the annual amount of depreciation accruing, it is true that the customers are contributing through rates paid for service an amount equivalent to a charge for depreciation.

Therefore, from the standpoint of adequacy of rates, the statement that if indebtedness is being retired, depreciation does not have to be accounted for, may be partially correct. It would be better practice, however, to carry a depreciation reserve and also a reserve for extensions and debt retirements on the books, the cash being applied to replacements, extensions or retirement of debt. Such a plan would allow the book records to reflect the true financial condition of the property at any time. The practice of not accounting for depreciation makes the statement of the financial position of the utility inaccurate.

Many cities have financed water systems from proceeds from general obligation bonds, and the interest and retirement charges are paid from funds acquired by taxation or by contributions from the water department to the general funds, or from both sources. Many such cities make no accounting for depreciation, nor do they keep books on any standard system of accounting.

It would be much better if some uniform system of accounting were adopted by means of which depreciation and other items are accounted for in a proper manner. Under such a plan, the utility accounting can be maintained on a basis that reflects the true financial condition of the utility, and one that is not influenced by the debt situation, which varies among cities and changes from year to year in each system.

Regardless of the debt structure, the utility accounting can be on a proper basis, the contribution of funds to meet debt obligations being made by cash from any reserve fund created. The point is that the accounting, so far as the utility is concerned, should be based upon the operation of the utility itself, and not governed by the financial situation that may exist as to debt service.

As stated above, it is common knowledge that depreciation in any physical plant does take place, and it would seem to be as apparent that the loss in service value due to it should be accounted for and made part of the cost of service. The determination of the proper amount to charge operations each year due to depreciation losses is not a simple one.

The rate at which materials and equipment depreciate or suffer loss in service value differs in all utility systems. This is true so far as physical causes are concerned and to a much greater extent from those of a functional nature. A water system in a rapidly growing city will usually have more accruing losses in service value than one of slower growth. This is due to the fact that pumps, mains and other units of property become inadequate more quickly due to increased demands.

Similar units of property may, and usually do, have different useful service lives in different systems. Unless a system has grown and is continuing to grow at a steady rate and has reached an age equal to that of the unit of property having the longest useful service life in that particular property, and it can be assumed that there will be no unusual changes in the art, any data taken from the records upon which annual losses due to depreciation could be based, would not be accurate. No property in the water utility field would provide such information.

There are at present several theoretical methods in use for estimating the annual rate of accrual of depreciation and for which equivalent annual allowances are usually made. The most commonly used methods are:

1. Straight-line method.
2. Sinking-fund method.
3. Service-life-present-worth method.

The above methods call for establishing useful service lives for the different units of property involved, which at best can only be approximately correct. These service lives are usually taken from some table based upon average figures or what may appear to be average figures from some one or a few particular systems. Such average service life figures may not even approximate the actual service life of the different units in the particular property for which annual allowances are being determined.

Any one of the above methods might be used as a basis for annual allowances for depreciation if the results are checked frequently and adjusted in accordance with actual accrued depreciation. The straight-line method does not give results consistent with the facts, however, since the service value of utility property does not diminish as a straight line. The sinking-fund and service-life-present-worth methods, while differing in theory, do not differ materially in results, and both recognize that, while a certain portion of the useful life has elapsed, the remaining service value is greater than indicated by the ratio of age to the estimated useful life.

It is apparent that a depreciation reserve established in accordance with these theoretical methods, if not checked against an engineering determination of the actual existing accrued depreciation, may soon become considerably greater or less than it should be.

Allowance for Retirement

Fortunately, these allowances which are made annually can be varied and the answer as to the correctness of the annual allowances is a periodic engineering determination of whether the balance in the retirement or depreciation reserve is adequate to cover the depreciation that has accrued in any particular system at some fixed date. It is possible to make, within reasonable limits of accuracy, an engineering determination of the existing accrued depreciation at any certain time, based upon conditions prevailing at that time.

Conditions may change later and cause the rate of diminution of service value either to increase or decrease, but for any current date a reasonably accurate measure can be obtained for testing the adequacy of the reserve. If the amount is greater than needed, the annual allowances can be reduced, or if inadequate, they can be raised. Such a check, made periodically, gives a logical and practical method of determining what such allowances should be, as well as checking the adequacy of the reserve.

The determination of proper annual allowances for retirement or depreciation and the adequacy of a retirement reserve are, from their very nature, engineering problems. Engineering appraisals of physical property are helpful in setting up a proper system of accounts, and an engineering determination of accrued depreciation is the best and only real means of knowing the actual amount of accrued depreciation existing at any fixed date.

What the depreciation reserve really represents is the amount of depreciation that has taken place in the property still in service, or, expressed another way, the property that has been used up in service and for which the utility has been compensated for through rates. While it is not necessary to hold the retirement or depreciation fund in cash, as it is usually more prudent to use the money for plant extensions or debt retirement, it still is, in principle, a trust fund, held to replace the used up property when retired and for which the consumer has already paid. It is evident that depreciation charges that are greater than actually needed would, if reflected in rates, place a greater burden on the consumer than is necessary or fair. Likewise, charges that are too low would be unfair to the utility.

The data obtained from the survey discussed above show that, in 107 cities recognizing depreciation in their accounting system, the total reserves in these cities is equal to 27 per cent of the total of depreciable property. This means, if that amount were justified, that 27 per cent of the depreciable physical plant still in operation had been used up in service, or, stated in another way, the physical plants have an over-all average physical and functional condition of 73 per cent.

As the figure of 27 per cent is an average, some of the systems have much larger reserves. It is believed that none of the plants reporting are in such low condition, as service would probably be impaired if they were. Most of the reserves in this group of cities appear to have been influenced largely by straight-line

methods of determining annual allowances. It is a good example of why the straight-line method is, as generally applied, too drastic and also illogical when compared to what actually takes place in the long-life properties. This is especially true of most water works properties. While it is good practice to have a reasonable excess in the reserve to take care of unusual and unexpected retirements, it is believed that in those 107 cities quite a number have been accumulating reserves at a rate in excess of actual requirements.

Many water departments are faced with demands for transfer of cash to other city funds. Many of these departments could avoid serious depletion of funds if their accounting system recognized depreciation and if an adequate book reserve were maintained for retirement or depreciation, as well as an adequate cash reserve for extensions or debt retirement.

Many cities carry large depreciation reserves in order to hold funds in the water department, which purpose is often justified; but it is believed that equal protection would be available through other reserve funds and the accounting be made more accurate thereby. A city may have the legal right to use funds from its utility department for other departments, but it should not do so unless the utility, by proper accounting, is shown really to have excess funds.

If such excess funds exist, it would seem proper to reduce rates rather than divert funds to other departments, as such practice is really indirect taxation. Utility department officials should insist on keeping the department sound financially and resist as far as possible the transfer of needed funds, which practice is followed in many places to the serious detriment of the department.

A notice has just appeared in the press which states that in one fairly large city water rates are to be boosted 33⅓ per cent, the increase being made to provide funds for postwar improvements, including a sewage disposal system, with, perhaps, a water softener and filter system. If the people in this city know all about what is to be done with money raised in this manner and are willing to be so taxed for it, the city no doubt has the right to adopt such a plan, and the case is only mentioned as an example of the use of utility funds for other departments.

It is hoped that soon all the water departments in the country will realize the advantages of following a uniform system of accounting and a universal recognition of the necessity of including in such systems the proper accounting for depreciation.

RECORDING DEPTH GAUGE WARNS OF INTAKE TROUBLES

By CARL LEIPOLD

Late Superintendent of Filtration, Winnetka, Ill.

Anchor ice, plant growths, sand and other material which obstruct water flow through intakes and intake strainers, are indicated by a recording depth gauge installed on a walkway in the intake well, at the Winnetka water plant. The maximum water levels, above and below the center-line of the intake pipe, shown on the 24-hour chart (Fig. 2) are recorded on a monthly report sheet. Unusual conditions shown by variable water levels are noted and explained on the gauge chart.

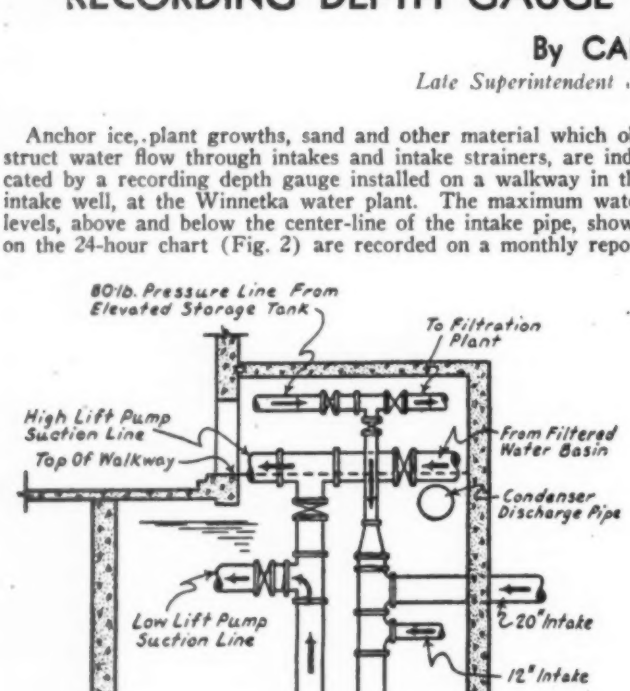


Fig. 1—Sketch of Intake Well Piping Arrangements, Winnetka, Ill., Water Works

The water supply of Winnetka is taken from Lake Michigan through two cast iron intakes, one of which is 20 inches in diameter and extends 3,000 feet into the lake and the other is 12 inches in diameter and is 2,200 feet in length. An emergency intake strainer is connected to the 20-inch intake at a point 1,000 feet from shore.

The intake well piping (Fig. 1) is assembled to allow filtered water from an elevated storage tank to be applied under 80 lbs. pressure directly to the intake pipes. Also the condenser cooling pond water from the power plant recirculating pump can be discharged into the intake well. With these connections, a pressure can be applied from the outlet end or intake well to the inlet end or intake strainers. Also the water level in the intake well can be brought higher than lake level. This arrangement has served favorably for eliminating the usual intake and intake strainer troubles, especially ice troubles.

Fig. 2—the water level chart—shows how anchor ice obstructing the water flow through the intake was eliminated on Feb. 16, 1933. The operator was aware from the chart record that anchor ice on intake strainers started shortly after 2 a. m., with the low lift pump operating at 2.5 M.G.D. rate. The low lift pump rate of pumpage was then throttled to 2.0 M.G.D., but proved to be of no assistance in eliminating the anchor ice on the strainers. At 8 p. m., with the water level dropping rapidly, the condenser cooling pond recirculating pump was regulated to discharge water at a rate of approximately 2.0 M.G.D. into the intake well. After a period of two hours, the chart indicated anchor ice troubles were being relieved, and at 12:30 p. m., indicated that the anchor ice had loosened from the strainers.

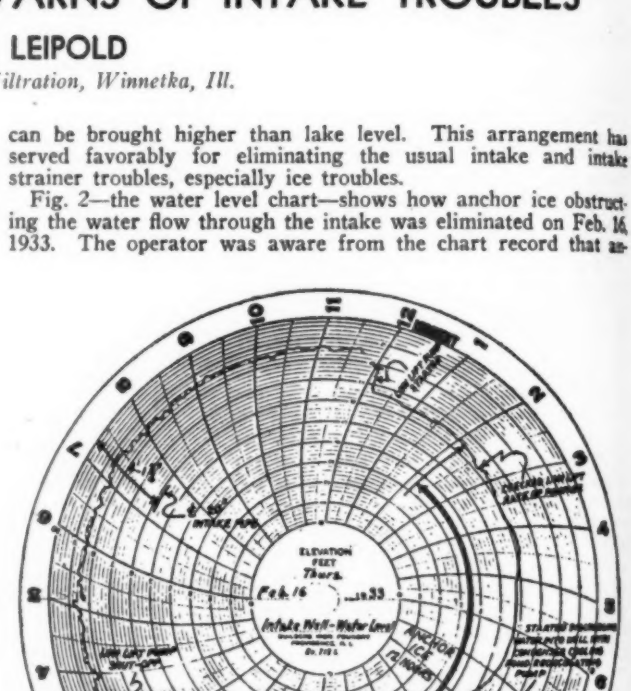


Fig. 2—Intake Well Water Elevator Chart. The Time and the Method Employed to Eliminate Anchor Ice on Intake Strainers Are Indicated

This method of chart records of water levels in intake wells has proven to be of much value as a warning to prepare for intake troubles, and the taking of measures necessary to eliminate them. The chart record also serves as an indicator of existing operating conditions when making intake capacity tests.

REGULATING WATER PIPING WITHIN BUILDINGS

By STEPHEN H. TAYLOR

Superintendent, Retired, Water Department, New Bedford, Mass.

In 1935 the City of New Bedford, Mass., set up regulations governing water service supply piping and fitures. The following year Mr. Taylor prepared this article for *Water Works and Sewerage* and the article last appeared in a Reference and Data issue in 1940.

On inquiry to Mr. Howard C. Mandell, present Supt. of the New Bedford Water Department, it was learned that these regulations have proved "workable, practical, and sufficient to accomplish the results for which they were intended."

In view of the success of these regulations during the 10 years of their existence we are reprinting them in this issue and adding Mr. Mandell's comments at the end.—THE EDITORS.

IN AN EFFORT to improve undesirable water service conditions in New Bedford, the Water Board adopted a set of rules and regulations which became effective June 1, 1935, governing the installation of house piping, which we feel will benefit the water department—but, more especially the public.

The city ordinances places the supervision of hot water tanks and water heaters under the jurisdiction of the City Board of Health. That department works in cooperation with our department regarding this equipment and has established rules which require that such equipment be installed in a manner which will be safe and prevent forcing hot water back to damage meters. The new regulations follow.

NEW BEDFORD WATER BOARD REGULATIONS GOVERNING WATER SERVICE SUPPLY PIPING AND FIXTURES† JUNE 1, 1935

(See separate pamphlet for sprinkler piping regulations)

Section I. Every water-taker shall pay the established rates for water supplied within the time and at the place specified upon bills rendered; shall at his own expense, keep the service pipes within his premises in good order and repair and protected from the frost; shall not allow the water to run to waste; shall not make any change in the service pipe between city main and meter, unless sanctioned so to do by the superintendent; shall not conceal the purpose for which water is used; shall allow the superintendent, registrar and persons authorized by them, or by the board to enter the premises supplied with water to examine the pipes and fixtures and ascertain the quantity of water used and manner of use, and shall indemnify the city for all damages it may sustain or be required to pay, in consequence of any injury resulting from any violation of these regulations by the water taker.

Section II. All applications for service supplies must be made by the owner of property at the office of the registrar in the form prescribed, stating the various uses to which the water is to be applied.

Section III. SERVICE FROM STREET—In every case the installation of the service pipe from the street main to the end of pipe where taker's stop with waste is installed by the plumber shall be made by the New Bedford Water Department, and the charge to the owner shall be as specified in regulation adopted by the Water Board February 6, 1924, viz.:

For installing one service to each property from the main pipe to street line as follows:

For ⅝ in. service	$31.00
For ¾ in. service	32.00
For 1 in. service	39.00

In cases where permanent pavement is disturbed, the owner is also required to pay for replacing the same.

For secondary services, temporary services or for services larger than one inch in size, the entire cost of installation, including cost of re-surfacing permanent street pavement.

For all services on private property, the owner shall pay the entire cost of such work.

†Regulations pertaining to inside piping and fixtures begin with Section VIII.

Section IV. Each service shall be provided with a satisfactory stop and waste cock with coupling (this stop shall be round way and of the same size as the service pipe) to be located always just within the basement wall, at the point where the service pipe enters, and the pipes within the building must be so arranged that the water can be drawn from them whenever there is danger of freezing. The department will not be liable for any damage resulting from a failure to observe this important rule.

Section V. No water-taker shall be entitled to any damages nor will any portion of a payment be refunded for any sudden stoppage of the city supply occasioned by an accident or otherwise, nor for any stoppage for the purpose of making extensions, alterations or repairs. In such an event the water-takers must guard themselves against the collapse of boilers and other injuries liable to result from stoppage of the water supply.

Section VI. No cross connections between the City supply and any other supply which is not approved as potable by the State Dept. of Public Health shall be permitted except those which are properly protected by double check valves of an approved type. Said check valves shall be approved by the Water Board and shall be regularly inspected at the expense of the owner of the property by a representative of the Water Department at such intervals as the Water Board shall determine.

Section VII. METER REGULATIONS.

a. One meter of standard type and of same size as the supply pipe must be installed upon each service connection. It may be located between the curb stop and building or within building. If within building, it must be placed at a point adjacent to shut off, where pipe enters through foundation wall. If outside the building, it shall be installed in a satisfactory box or pit not less than 3 ft. x 4 ft. x 4 ft. deep. All meters 2 inches or larger shall be equipped with a by-pass capable of supplying the premises when the meter is removed for repairs or test. This by-pass valve to be kept sealed shut except when meter is out. (See Sketch.)

b. In all cases where one service connection supplies two or more separate consumers, or a block occupied by divers parties, only one meter will be used and the water rent as registered by said meter shall be charged to and payable by the owner of said premises or building. If additional meters are desired to ascertain sub-division or such supplies, they will be furnished at the expense of the applicant, who must assume all responsibility of reading and maintaining same.

c. Owners of property will be given option of either purchasing a meter outright and paying for its installation, or of having city furnish and install same and paying an annual rental therefor.

d. The property owner must keep the meter within his premises easily accessible for reading at all times. The city will include all repairs due to ordinary wear in its rental charge, but in all such cases, the owner will be held responsible for proper protection of the meter from all damage which may occur due to freezing or from hot water backing from overheated house boilers or other causes. Property owners will be assessed the cost of repairs of every nature necessary to properly maintain the meter owned by them. In case payment of such charges is not made upon demand, the water will be shut off from the premises supplied, and will not be renewed until after such charges, including the additional sum of one dollar, to cover expenses of shutting off and letting on the water, shall have been paid.

e. The owner of property shall pay at the established meter rate for amount registered, whether used or wasted. The water department will not assume any responsibility for use of water within metered premises.

f. Should a meter fail to register for any cause, the quantity shall be determined and the charge made based on average amount registered by meter when in order.

g. After a meter has been installed, it will not be removed for purpose of rating the premises supplied on any other basis of water charged.

h. No meter shall be discontinued from the pipe, moved or disturbed, without permission from the water registrar, who will send a properly authorized person to attend to any change needed.

i. If a house becomes unoccupied, the owner or agent may have the water shut off and the meter removed during the

period of non-occupancy by making a request therefor to the water department, and paying one dollar to cover expenses.

Section VIII. PLANS TO BE APPROVED—Plans of proposed new installations, extensions or alteration of existing systems, showing proposed sizes and materials, must be filed with the Water Board, and approved by said Board or its designated representative before starting work.

Section IX. INSIDE PIPING—All inside installations shall be made under the direction of a registered Master Plumber, except in manufacturing plants or other plants where competent pipers are regularly employed. Connections to supply water heaters, hot water storage tanks, heating and ventilating apparatus, cooling systems and power plant equipment and apparatus may be made by competent employes of persons regularly engaged in the business of installing such apparatus, subject to the inspection and approval of the Water Board. Each holder of a Master Plumber's Certificate of License shall register his name and business address with the Water Board on or before the first day of May in each year. Notice of any change in the place of business shall be given immediately to said Water Board.

Section X. INSPECTION AND TEST—On completion of the installation it shall be inspected and approved by the designated inspector of the Water Board before the water supply will be turned on to the premises. It shall be tested in the presence of the inspector at city water pressure.

Section XI. KIND OF PIPE—All water supply pipes and fittings, shall be of lead, brass, copper or other non-ferrous metal or composition, except in the case of pipes four inches or more in diameter, in which case, cast iron pipe properly coated and lined with material approved by the Water Board may be used.

In order that piping shall be sufficiently strong to withstand City pressure with a reasonable allowance for corrosion all pipes must comply with the following minimum specifications.

LEAD PIPE:

All lead pipe for water service shall be made from soft virgin pig lead without any admixture of scrap lead or any other material and shall weigh not less than

For ½ in. pipes	3	pounds per foot
For ⅝ in. pipes	3½	pounds per foot
For ¾ in. pipes	4½	pounds per foot
For 1 in. pipes	6	pounds per foot
For 1¼ in. pipes	7¾	pounds per foot
For 1½ in. pipes	11¼	pounds per foot
For 2 in. pipes	19½	pounds per foot

BRASS PIPE:

All brass pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Brass Pipe, Standard Sizes" Serial Designation B43-23, with the exception of Paragraph 4 thereof. In place of the said Paragraph 4, the brass shall conform to the following requirements as to chemical composition:

Copper, minimum	59.00%
Lead, maximum	0.50%
Iron, maximum	0.07%
Zinc, or Zinc and Tin	Remainder

This change admits use of so-called "Admiralty" and "Red" brasses.

COPPER PIPE:

All copper pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Copper Pipe, Standard Sizes," Serial Designation B42-23.

COPPER TUBING:

All copper service tubing used for underground piping shall conform with the Standard Specifications of the American Society for Testing Materials for Copper Tubing, Government Type K, Serial Designation B88-33. For interior piping copper tubing, Government Type L, is allowable.

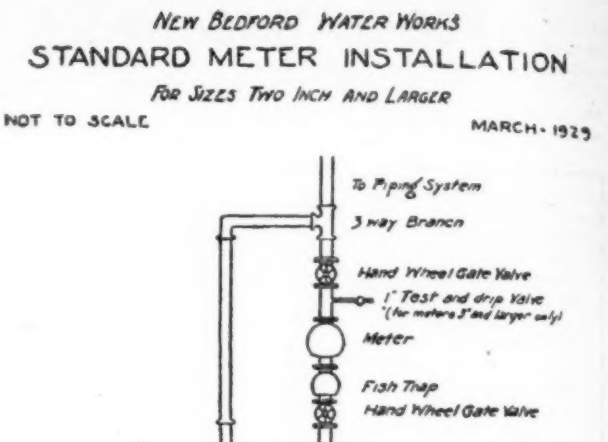
Fittings for use with brass or copper pipes shall be of material and strength corresponding with the pipe used. All installations shall be made in a thorough and workmanlike manner satisfactory to the New Bedford Water Board.

Pipes which are to be concealed in partitions or otherwise shall be tested as specified in Section X before being concealed.

No pipes which have previously been used for other purposes shall be used for distributing water.

Section XII. PROTECTION—All concealed water pipes, storage tanks, flushing cisterns, and all exposed pipes or tanks subject to freezing temperatures shall be efficiently protected against freezing.

Section XIII. DISTRIBUTION—The water supply shall be distributed through a piping system entirely independent of any piping system conveying another water supply.


NEW BEDFORD WATER WORKS
STANDARD METER INSTALLATION
FOR SIZES TWO INCH AND LARGER
NOT TO SCALE
MARCH - 1929
To Piping System
3 way Branch
Hand Wheel Gate Valve
1" Test and drip Valve
(for meters 3" and larger only)
Meter
Fish Trap
Hand Wheel Gate Valve
3 way Branch
By-Pass Valve
Taker's Main Gate (Optional)
Building Line
Street Line
City's Main Gate
City Main
Where continuity of supply is essential, it is recommended that gates be installed in street main on each side of service connection, as shown.

Standard Meter Installation, New Bedford Water Works.

Section XIV. WATER SERVICE—The water service pipe of any building shall be of sufficient size to permit a continuous ample flow of water to all fixtures on all floors at a given time.

Section XV. SUPPLY TO FIXTURES—All plumbing fixtures shall be provided with a sufficient supply of water for flushing to keep them in a sanitary condition and shall be adjusted to prevent waste of water. The water from water closet and urinal flush tanks shall be used for no other purpose.

The bottom of flush tanks for water closets or urinals shall be above the overflow level of the fixture when drain is obstructed.

All flushometer valves for water closets shall be equipped with a vacuum breaker of a type approved by the Water Board.

The supply pipe for each tenement or bathroom shall be not less than ½" inside diameter and connect to the main supply pipe, which shall be not less than the size of the main service. The main service shall be carried full size to the point where the last branch is taken off in the basement.

Accessible shutoffs with waste shall be provided in the basement which shall separately control the water supply for each tenement and for each hot water tank.

Section XVI. SIZE OF PIPES—The minimum size of water-service pipes from main to the dwelling shall be five-eighths inch, and to fixtures as follows:

Sill Cocks	½ in.
Hot Water Boilers	½ in.
Laundry Traps	½ in.
Sinks	½ in.
Lavoratories	⅜ in.
Bath Tubs	½ in.
Water Closet Tanks	⅜ in.
Flushometer Valves for Water Closets	1 in.
Flushometer Valves for Urinals	½ in.

Two outstanding cases of potential pollution from back syphoning have recently come to the attention of our inspector. One was in a large High School; the other in a department store of importance. These cases and many others show the need of constant vigilance on the part of someone, and we in New Bedford have decided that the Water Department should

assume this responsibility as there is a possibility that pollution from such sources may even get back into our mains by siphonage or gravity when it becomes necessary to shut off the mains.

The inspection has been placed in the hands of a Master Plumber of long experience who has the respect and confidence of other master plumbers. He is a full time employee of the Water Board and has the complete cooperation of the plumbing inspector of the City Board of Health.

The new regulations have been in effect since June 1st, 1935, and the results have been very satisfactory. The master plumbers cooperate very well with us as it protects them against unfair competition of unlicensed men and inferior materials. The public gains by being assured of proper supply and approved water fixtures. The department gains by being relieved of many complaints which come about as the result of improper materials or workmanship.

No matter how complete the main distribution system and service connection may be, the consumer will not get the supply he is entitled to at his fixtures or the protection against pollution within his own property unless someone sees to it that proper interior piping and fixtures are installed in an approved manner.

Our City Solicitor has ruled that the supervision of the entire water supply (except water heaters and hot water tanks), up to and including proper fixtures, is within the jurisdiction of the Water Department.

1945 Comments on Above Regulations by Howard C. Mandell, Supt.

We have found the 1935 regulations workable, practical and sufficient to accomplish that improvement in the construction, alteration, extension and materials of water piping on private premises for which they were intended.

More than 6,000 permits have been issued to master plumbers and competent maintenance personnel in our numerous large industries during the past ten years. Through preliminary discussion of proposed installations and through inspection of existing installations we have discovered several hundred cases of poorly designed or unsatisfactory connections or conditions and have secured remedies.

We are fortunate in having as our piping inspector a particularly well qualified individual, James F. Murphy, a master plumber with many years of practical experience, a plumbing instructor in our vocational school and a close student of the potential dangers of faulty water pipe installation.

We are fortunate also in that we have in the New Bedford Vocational School a laboratory wherein visual demonstrations of dangerous cross connection and plumbing conditions are given, using colored fluids and transparent sections of plastic tubing and standard plumbing and pipe fittings of everyday common occurrence. The educational presentation of material at this laboratory to the plumbing trade and to public health officials and others interested in the matters of back-siphonage and cross connection has been of very real assistance in securing the cooperation of all these groups and individuals.

The only change we have found necessary has been the relaxation of the prohibition against ferrous pipe because of the scarcity of copper and copper alloys during the war. We have issued conditional permits allowing the use of iron and steel pipe when materials as specified by the regulations were unobtainable. It is our intention to re-inspect such installations at annual intervals and inform the owners of the necessity for change.

The regular collection and examination of samples for bacteriological quality, particularly at those places and in those areas where back-siphonage or cross connections may be expected, is a valuable indication to the department whether satisfactory piping conditions exist throughout the system.

If it is known that sterile water is delivered into the distribution system, but that samples from certain outlets on the system contain bacteria evidencing contamination, special inspections of the buildings or areas suspected can be undertaken and dangerous conditions can be discovered and corrected.

We feel that through the enforcement of our piping regulations, and through the analyses of as many samples from the distribution system as a limited staff is able to make, we are doing the best we can to assure that pure water is furnished to all our consumers.

Laboratory, in New Bedford, for visual demonstration of dangerous cross connections and plumbing conditions

Low Cost Insurance
FOR SERVICE PIPING

STREAMLINE Copper Service Pipe represents one of the lowest cost forms of insurance that water works officials, who are responsible for the return on a heavy capital investment, can adopt.

In normal times STREAMLINE Copper Pipe compares very favorably in cost with ferrous pipe, yet with the exception of certain abnormal soil and water conditions, it never has to be replaced due to rust or internal corrosion. Consequently, there is no discoloration of the water nor decrease in volume or pressure, such as is invariably found, after a few years, with corrodible piping.

Leaks due to vibration are eliminated. A STREAMLINE Copper Service Pipe installation is practically vibration proof, settlement of filled earth or water mains have little or no effect upon it. Its quality of ductility permits sufficient stretch to take care of this condition without failure of the pipe.

STREAMLINE Service Pipe (Type K) is the original copper service pipe, and the first to be produced in America for water service work. It is the most uniformly soft and pliable pipe possible to secure—it is kept that way through the use of the best copper obtainable for the purpose and through strict laboratory control through every phase of its manufacture.

When your plans call for pipe and fittings for replacement or for postwar work, carefully consider STREAMLINE. Its use will repay you many times over.

STREAMLINE
PIPE AND FITTINGS DIVISION
MUELLER BRASS CO.
PORT HURON, MICHIGAN

ELIMINATION OF CROSS-CONNECTIONS IN LOS ANGELES

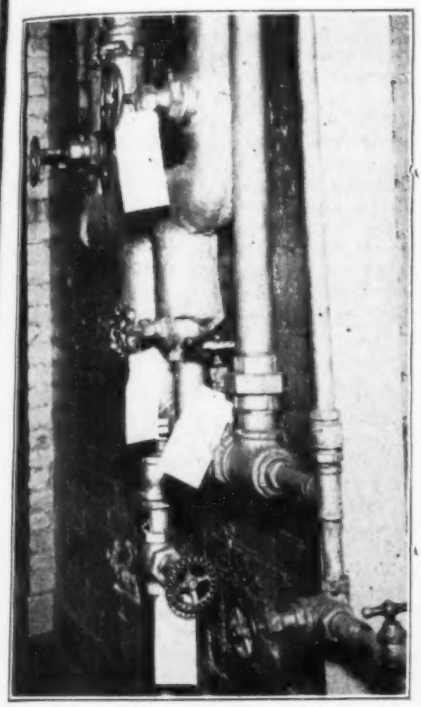
By R. F. GOUDEY

Sanitary Engr., Dept. of Water and Power, Los Angeles

THE city of Los Angeles has eliminated over 40,000 cross-connections, since the outbreak of the war, in its program to protect domestic water at harbor waterfront properties, military facilities, federal housing projects and war production plants. The project involved the installation of 10,000 vacuum breakers on plumbing fixtures, the raising of 21,000 inlets to give air-gap protection, the breaking of 2,000 direct connections to sewers, and the installation of over 2,300 backflow mechanical devices on pressure lines. The work involved over 2,000 properties, 1,200 different owners, and exceeded a cost of $2,000,000.

Historical Development of Cross-Connection Protection

From 1930 to 1938 the Department of Water and Power carried on a program to eliminate plumbing hazards and all types of cross-connections. With cooperation of the Building and Safety Department, an ordinance was passed in 1938 covering the installation of approved vacuum breakers on the discharge side of water inlets to plumbing fixtures, much as is covered by the most progressive plumbing ordinances throughout the country. The program at that time involved complete separation of potable and non-potable water piping systems and supplies. A few large fire services were permitted to have double check valves where special specifications were followed as to tight closures and material used, but their general adoption was disapproved.



1-in. *City Water Line (right) Cross-Connected to 2-in. Boiler Feed Water Header on Pump Discharge (left).*

Early in the program it was recognized that the policy of requiring complete separation was not only overly expensive but gave fictitious protection. It was found at photographic and plating plants where air gap protection had been obtained, that in subsequent inspections hoses had been placed on the inlets to avoid splash and to secure mixing. At waterfront properties where fresh water connection to salt water pumps and salt water piping systems had been broken, new connections had been made because it is imperative to flush combination fresh and salt water lines after every period of salt water use.

On oil well leases where tanks with rim discharge inlets and pumps had been installed to prevent backflow from oil well drilling operations and from boiler use, cross-connections were invariably made around the air-gap protection in order to secure city water pressure for fire protection. As long as property owners have what they consider as legitimate incentives to use city water under pressure, just so long will there be danger of surreptitious cross-connections being made. Based on these experiences, it is believed that *only by the proper installation of dependable mechanical devices will domestic water piping systems ever approach safety.*

Development of Mechanical Devices

The development of mechanical devices to safeguard domestic water lines has been discouragingly slow. Superior types of double check valve installations, except for some improvements in pins, bushings and clapper seat material, are fundamentally the same as they were twenty-five years ago. Double check valves have never been generally accepted as adequate protection between safe and unsafe water supplies, largely because the forces creating backflow are neither controlled nor dissipated.

An effort was made to install pressure differential relief valves which would provide openings to atmosphere under backflow conditions. An "economy" valve was developed for this purpose but did not prove satisfactory. A device with an automatic opening to atmosphere represents a most fruitful field for immediate exploitation because it destroys backflow possibilities into the water supply. Some consideration was given to a number of "switch-over" type valves to separate two supplies but which do not separate their piping systems and consequently permit polluted water to backflow after resets. It appeared, therefore, that entirely new devices would be needed and manufacturers rose to the occasion.

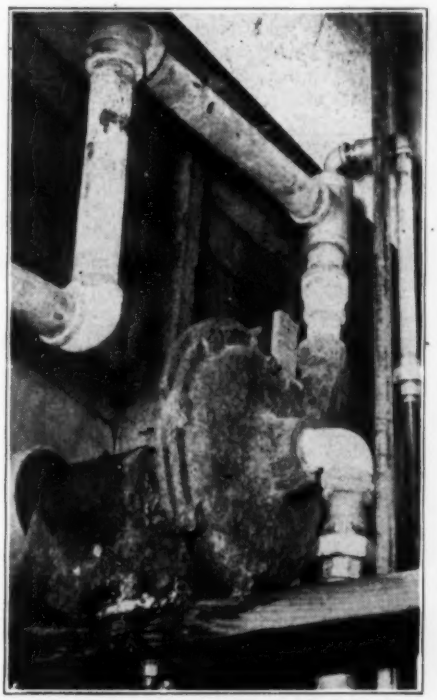
Backflow Pressure Protective Devices

The first backflow pressure protective device was a semi-manual operated Entriken valve installed at a Los Angeles swimming pool in August, 1933, followed a few months later by a second installation at another swimming pool. It provided an air-gap and back-pressure check but was not automatic. In 1938 Mr. Frank Carlton conceived of changes whereby with the addition of a vacuum breaker and the inclusion of a bellows-operated pressure differential relief valve, the device could become automatic.

With additional structural improvements this valve became the E-C Valve No. 3 for sizes ½ in. to 4 in. and was extensively used from 1939 to 1943. In 1942 an E-C Valve No. 5 was developed and one was installed which is yet the very latest in backflow protection, but is too costly for the average installation. A streamlined E-C Valve No. 6 appeared in 1944, incorporating many of the latest and best features in backflow protection and for more critical conditions has superseded the E-C Valve No. 3.

Two other companies entered the field during 1939-40. One was the Schaffer Engineering Co., which submitted the Empire valve. This device met test requirements but was too costly to commercialize. The second was the Ross Combustion Engineering Co., which produced a valve in ½-in. to 2-in. sizes for use on boiler, steam and hydraulic elevator lines. For the protection afforded, this valve still is superior from the standpoint of cost.

The Clayton Manufacturing Co. next entered the field and by 1943 was an active competitor. The company specializes in check valves and altitude control valves and combined them to make up an assembled backflow protection unit employing standard equipment. Their first unit (Clayton No. 15) included two check valves,



2-in. *Salt Water Pump with* 1-in. *City Water Priming Line on right (no valve in picture).*

a vacuum breaker and a pressure differential relief valve which operated on the same principal as the E-C Valve No. 3. A second development was a unit (Clayton No. 1) in which both checks were power operated. This device when adjusted to give positive air-gap protection under reverse flow conditions approaches the best type of protection available. Both types of valves have been widely installed during the current year.

Three national concerns have submitted devices during the past year but only one of these companies was successful in producing an approved valve. This is a Hersey No. 2 unit which includes two fire detector check valves, a vacuum breaker, and a pressure differential release valve. It locally meets the requirements of the Board of Fire Underwriters and some units have already been installed.

As the reliability and availability of backflow prevention units gained ground, the previous rigid policy of complete separation of potable and non-potable supplies and piping systems relaxed. Experience so far has completely justified such action. A practice of "industrializing" lines at large plants was instituted. In plants having a large number of cross-connections, a point in the domestic system was selected for the installation of a backflow prevention device to isolate the majority of cross-connections. The former section of the domestic system beyond the device was identified by color bands and by posting at each outlet to designate it fully as an industrial line.

All former domestic water outlets were transferred to safe ence so far has completely justified such action. A practice domestic lines and in some cases short extensions were found necessary. This practice greatly reduced the cost of over-all protection and gave the consumers the greatest use of the city supply with no incentive to make additional cross-connections.

¾-in. By-pass Installed Around Air Gap Tank and Hidden in Grass.

Desirable Features in Backflow Protection Units

Some of the desirable features of satisfactory backflow protection units are:

(1) Provision for a central zone in which there is at all times less pressure than on the inlet side by providing a pressure differential release valve which opens the central zone to atmosphere with an operating head less than the initial loss-of-head past the inlet check, except when the city pressure is at or less than 2 lb. per sq. in.

(2) A drain connected to the pressure differential release valve sufficiently large to waste a reasonable amount of leakage past the outlet check without building up a head in the central zone of more than 2 lb. per sq. in. pressure when the inlet pressure is zero.

(3) No excessive spitting of water because of sudden drops on the inlet side.

(4) Control diaphragms in duplicate with a vent to atmosphere between them to avoid any danger of a cross-connection being created by diaphragm failure.

(5) Vacuum breakers included where the location of the device is at high points in the piping systems or where pumps take a suction on the inlet side of the device.

(6) Some visible positive sequence such as an alarm or water spurting to atmosphere to indicate any failure of any functioning part of the device.

(7) A location so the device will not be flooded.

(8) Adequate protection against damage from ice in freezing weather locations.

The earlier devices, including the Hankin Valve of Montreal, contain intermediate zones of higher pressure under backflow conditions than exist on the inlet side. This is objectionable because in case the inlet check leaks as much or more than the discharge check, the relief valve cannot open and backflow is unchecked. The trend, therefore, is toward the use of installations having protection zones of less pressure than on the inlet side.

Backflow Preventer (Clayton Type) on Domestic and Fire Services from Common 4-in. Inlet at Center (Vertical Line entering from Back Between Two Gate Valves). (a) Line to right contains check valve, vacuum breaker, check valve, pressure differential release and check valve. (b) Line to left same sequence but vacuum breaker is on the other side.

Cross Connection Research

The University of Southern California has established a $30,000 Foundation on Cross-Connection Research and Testing in which it is hoped that the basic principles of backflow protection can be properly evaluated; that all mechanical devices can be made correct from an engineering standpoint; and that adequate test rules can be formulated. A laboratory for this purpose is nearing completion. The Foundation is backed by many manufacturers of national standing, by local and national master plumbers' organizations, and by individuals familiar with the problem.

The war speeded up cross-connection work. Only three men were engaged in it from 1930 to 1941 inclusive, although by the end of this period cooperation had been secured with other city departments so that the net effect was the equivalent of more than three men.

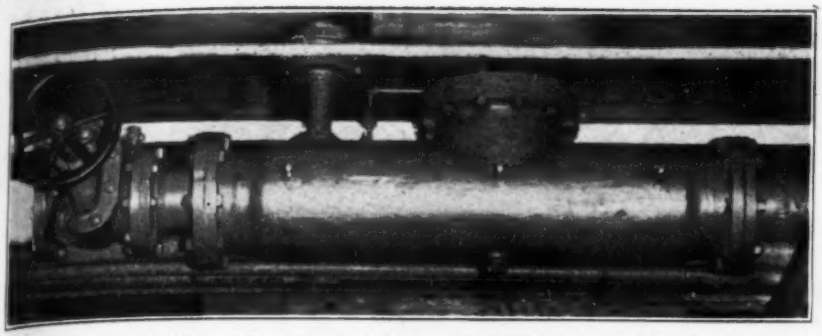
Cross-Connection Central Committee

During the spring of 1942 in order to have a more agressive program and a more uniform city policy for new construction, as well as for existing installations, a cross-connection control advisory committee was created by a joint resolution of four Los Angeles city departments covering health, water, building and safety, and mechanical engineering. The program at its peak included eighteen inspectors.

The resolution set up the author as chairman, and Mr. Roy O. Van Meter as chief inspector. The Department of Water and Power furnished office space, an office engineer and a field supervisor. The plan included assignment of twelve plumbing inspectors with rotation of others for inspection and training purposes in field work and these men were paid by the Department of Water and Power.

The Health Department at times assigned up to four men for instruction. All inspectors were cross-deputized so that police power was available regardless of the type of cross-connection discovered. Later this deputization was declared illegal, but this decision came too late to interfere with the program. The resolution required that the committee develop a unified program and so far as possible to proceed on a broad educational basis.

The merits of the cross-connection program were carefully



Industrializing 6-in. Shipyard Line with E-C No. 6 Under Wharf
(Note vacuum breaker on left. Waste valve on pressure differential is on other side. Three test cocks are on side. Inlet side is on left.)

explained to each plant owner on the basis of health and protection and added security. It has not been necessary in any case to resort to legal action. The educational program has been carried to the point where plumbers, insurance agents, boiler inspectors, hospital managers, equipment manufacturers and federal security officers have become conscious of the need of backflow protection and have actively participated in the work. The records indicate that 45 per cent of the pressure type of backflow prevention devices installed in Los Angeles were the result of this cooperation.

The committee took cognizance of the effect that cross-connections might have on the war effort and immediately intensified its program. First, a complete survey was made of the waterfront area at the harbor which included Navy, Coast Guard, Army, Air Corps, petroleum, and shipyard facilities. Secondly, a complete survey was made of all war production plants throughout the city, including all aviation plants, refineries, metal industries, colleges, housing projects, and all other plants on "master responsibility lists." Thirdly, investigations were made of all new water devices.

Early in the program there were several cases of waterfront pollution affecting military personnel because of carelessness in the use of pierhead outlets. Los Angeles has had no case of backflow for nine months, which is a remarkable record when compared with what is happening at the other ports similarly engaged in the war effort.

Elimination of Cross-Connections

Very careful consideration must be given to thoroughness in making inspections, care in office review as to requirements and remedies applicable, and presentation of recommendations to management if success is to be attained in cross-connection elimination. The following procedure was carefully exercised:

1. Before making any field inspection the following preliminary steps were taken:

(a) *A tracing of the area to be surveyed was made from a district sheet of the Water Dept., giving on a scale of* 100 *feet to the inch, the size of street mains, location, service numbers of the water services, and similar pertinent data.*

(b) *Information was collected from service cards giving number and size of meters, owner's name and address, and data as to meter setting with turn-on and turn-off data.*

(c) *Management was contacted to explain the historical background in connection with the purposes of the survey, the logic and reasons for cooperation in eliminating cross-connections on a uniform plan, the law backing up enforcement requirments, and an explanation of typical cross-connections and how they can be eliminated.*

(d) *Management was asked to provide proper passes to enter the premises and to appoint a water supervisor or other person to assist in the survey.*

2. In the field, inspectors prepared drawings of lines, fixtures and water equipment actually seen by them and accurately covering the following:

(a) City service connections.
(b) All city water, industrial, and process pipe lines.
(c) All plumbing fixtures as to type and size.
(d) All pumps and dual systems, regardless of function, together with pressures and practices of operation.
(e) All water using equipment.
(f) All sewers and drains.

3. Inspectors in the field made such water-use tests as to check on the accuracy of their maps and determined reasons and incentives for every cross-connection discovered.

4. Inspectors in many cases secured blueprints of water lines from management and used them only after careful verification. In many cases management requested copies of the inspector's drawings as being better than theirs so far as water piping plans were concerned.

5. Office work was carried on with equal assiduity covering such items as:

(a) A review of each cross-connection and a discussion as to the best and most economical manner to secure protection.
(b) A writing up of all cross-connections by use of standard terminology, together with remedies similarly expressed.
(c) Checking of all recommendations by office and field supervisors.
(d) Complete consideration of all legitimate city water uses which could possibly be anticipated so that there would be little danger in the future of new cross-connections being made.
(e) Issuance of recommendations in legal form setting forth instructions, laws violated, and enforcement agencies involved.

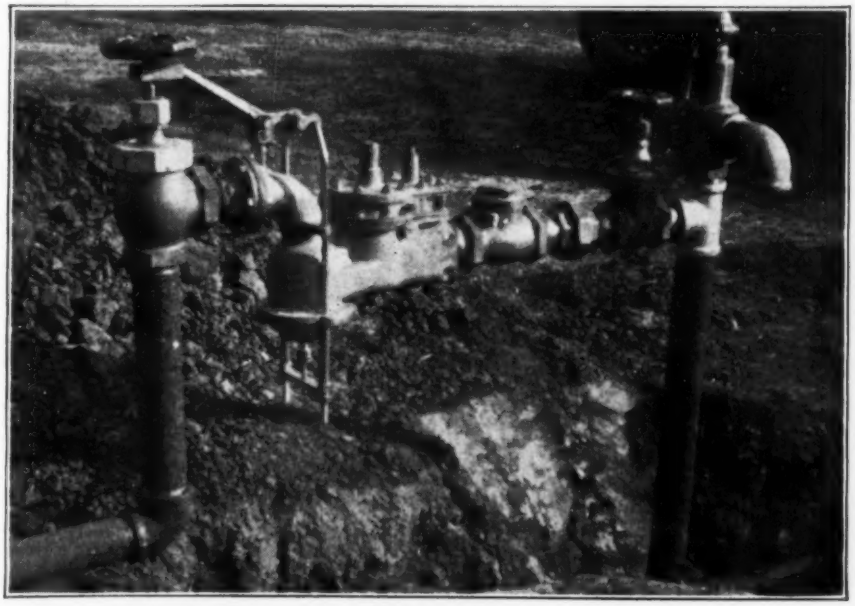
6. Proper serving of the recommendations to management is important and involves:

(a) Conferences with key personnel in which the program as a whole is again reviewed.
(b) Timing with recommendations of orders from Industrial Accident Commission, Naval and Army security officers, and interested agencies.
(c) Special efforts to explain any misunderstanding that field men at the plants may have in regard to specific recommendations.

7. Reinspections and contacts are necessary to follow up progress of the work and to lay foundation for subsequent regular inspection after completion.

8. All cross-connections must be eliminated before the file is closed.

As the program commenced in earnest the Cross-Connection Control Advisory Committee approved of a seven-point program

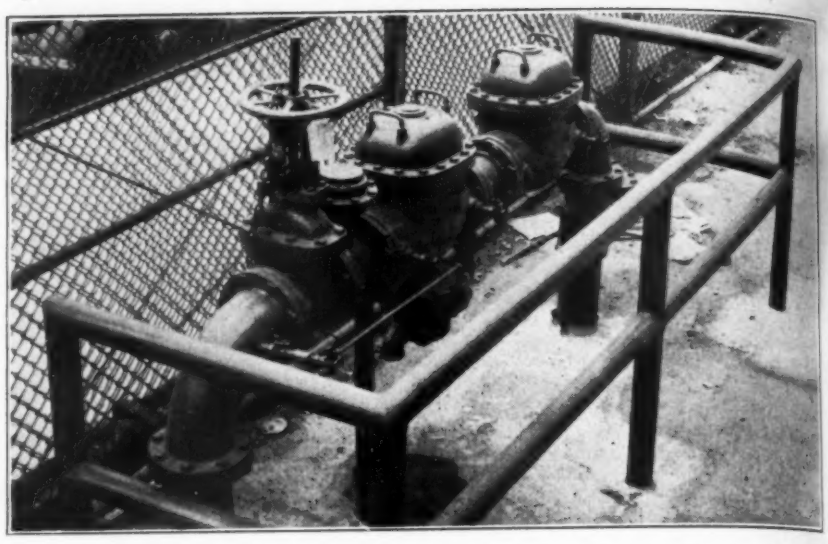


City Service (left) to Oil Lease (right) Showing 1938 *E-C No. 3 Valve and Pressure Safety Valve (top right) in Addition to Relief Valve on Device.*

in cross-connection control which was endorsed by Army, Navy, and public health officials at a meeting on Sept. 15, 1942, at the Naval Operating Base, Long Beach, Calif. Because this outline was carried through unchanged it is repeated here as follows:

Seven Point Program

1. Backflow protection at meter of all services to premises fronting on the harbor and to adjacent industrial and commercial plants.
2. Backflow protection at the wharf for all ship supplies.
3. Segregation of domestic and fire lines as far as possible so that no unprotected cross-connections will endanger the domestic supply from pierhead, siamese, or salt water pump intakes.
4. Elimination of all dangerous plumbing inter-connections.
5. Provision for the isolation of all pipe lines carrying processing water.
6. Adoption of color and sign scheme for designation of safe and unsafe water lines.
7. Organization of water foreman on each premises to carry out a unified plan.



6-in. Hersey No. 2 Double Check Valve Installation with Vacuum Breaker at Right of Gate, and Pressure Differential at Bottom Between the Two Checks. (Fire service approved by local Board of Fire Underwriters' representatives.)

Every conceivable type of cross-connection was discovered in this survey with such odd ones as cooling coils for X-ray tubes and direct connections to sewers through blood plasma equipment. The survey included 300 oil well properties. While the category of cross-connections was much longer than indicated in this report, the following summary is of value in pointing out the main dangers involved.

Results of this tabulation indicate that there are more direct connections to sewers through flush valves than through equipment. Accordingly, every city should wage vigorous programs in the correction of faulty plumbing. The majority of low inlets can be eliminated by mere raising, although in some cases vacuum breakers on the discharge side of valves are justified. The use of mechanical devices under pressure is largely outside the field of plumbing and involves protection against pumps for cooling, process and industrial waters as well as dual water and oil supplies. All direct connections to sewers should be physically broken.

A wide range of devices has been used to prevent backflow. The first group is vacuum breakers on the discharge side of the water inlets to plumbing fixtures or submerged gravity inlets to tanks, requirements for which are covered by American Association Standards (A40.4—1942; A40.6—1943). The second type covers pressure-operated vacuum breakers and backflow protective devices which operate on pressure systems. The following tabulation indicates the magnitude of cross-connection elimination by use of devices:

Types of Back-Siphonage and Backflow Devices

		Number
A.	Plumbing type vacuum breakers	
	1. Flush valves	4,000
	2. Low inlets	10,000
	Total	14,000
B.	Pressure type backflow devices	
	1. Vacuum breakers only	200
	2. Backflow prevention	
	Industrial lines	1,232
	Dual supplies	360
	Meter protection	778
	Total	2,570
C.	Double check valves (150 with relief valves)	200
	Grand total	16,770

It is of interest to note the number of backflow prevention devices for different pipe sizes and that the most recent trend is to replace double check valves with complete devices, even for the larger sizes. The need for devices in sizes ¾-in. to 2-in. is apparent.

The cost to consumers for the entire program exceeded $2,000,000 with half of the work on the correction of plumbing fixtures, with about $500,000 involved in pressure backflow devices, and about $500,000 on pipe system changes to industrialize lines, parallel piping and breaking of sewer connections. Twenty-five contracts exceeded $25,000 and one contract reached $267,000.

Types of Backflow Protection Devices Giving Superior Protection

	E-C Valves	Clayton	Ells	Double Checks* (Hersey)	Double Checks* (Rensselaer)	Double Checks* Rebuilt	Total
¾"	128	3	18	—	—	—	149
1"	406	52	46	—	—	—	504
1¼"	373	56	69	—	—	—	498
1½"	57	60	12	—	—	—	129
2"	272	155	23	—	—	—	450
2½"	29	101	—	—	—	—	130
3"	74	50	—	—	—	—	124
4"	18	105	—	4	—	20	147
6"	19	34	—	29	2	50	134
8"	—	8	—	20	27	36	91
10"	—	—	—	1	1	5	7
12"	—	1	—	3	—	3	6
Total	1,376	625	168	57	30	114	2,370

*150 of these units have pressure differential relief valves.

Summary of Cross-Connections Discovered
Jan. 1, 1942—Oct. 1, 1944

		Number	Total Number
1.	Plumbing—55%		
	Flush valves and flush urinals	3,504	
	Low inlets	6,674	
	Minor hazards	12,487	
			22,755
2.	Equipment—26%		
	Low inlets	8,015	
	Steam, boiler	2,080	
	Air, compressors, elevators	257	
	Washington	364	
			10,716
3.	Dual supplies—9%		
	Salt water pumps	83	
	Wells, oil wells	330	
	Industrial, process and recirculation	1,846	
	Pierhead connections	1,265	
	Siamese connections	94	
			3,618
4.	Sewer—5%		
	Direct connections	1,747	
	Ejectors, water-operated	174	
			1,921
5.	Miscellaneous—5% (inter-street services; lawn sprinkling)		2,337
	Total		41,347

SIMPLEX VALVE & METER COMPANY

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SIMPLEX stands for LEADERSHIP in WATER WORKS & SEWAGE EQUIPMENT

TYPE MO METER

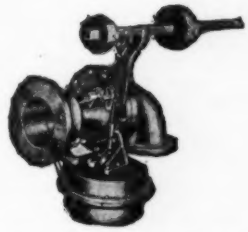
Indicates, records and totalizes fluid flow rates. Consistent high accuracy over wide flow range (up to 43 to 1); extreme sensitivity to every change in flow; simplicity of design, trouble-free operation, minimum maintenance cost. Evenly graduated, direct reading flow scale and chart. Floor stand, wall bracket or Panel Board mounting.

BULLETIN 300

TYPE MS FLOW RATE METER

Accurately indicates, records and totalizes flow rate. Bell-shaped float automatically extracts the square root of the law of flow and makes possible the direct reading chart —evenly graduated from 0 to maximum. The arm of the recording pen connects directly with the float for inevitable accuracy of transcription and sensitivity to flow change.

BULLETIN 350



RATE OF FLOW CONTROLLERS

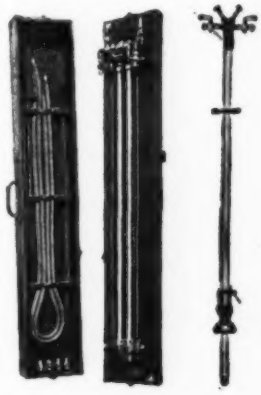
For gravity or pressure Filters, Clearwells, etc. A direct acting, balanced valve type controller, operated by a Venturi tube located in the effluent line. Lowest obtainable head losses when wide open; highest degree of accuracy without compensating mechanisms; largest possible ratio from maximum to minimum rates with any given size of unit; no electrical mechanisms used in operation. The controller starts quickly from a wide open position and takes the set rate in less than 15 seconds. Adapted to various types of clearwell control.

BULLETIN 250

AIR INLET VALVE

Eliminates the possibility of collapse of pipe line walls due to sudden drop in pressure in gravity flow line. The non-collapsible float is buoyed by the water in the line until a condition arises which tends to create a vacuum—then the buoying effect of the water is lost, the float drops from its seat, to admit air and destroy the vacuum.

BULLETIN 125



PITOT EQUIPMENT

Check the operating efficiency of distribution systems, pumps, meters. Panel board, portable, or stationary Recorders, manometers, and pitot tube types of equipment for accurate surveys—at low cost and with small expense—effect definite savings in operating loss.

BULLETIN 50

GAUGES

Indicating, recording, and/or totalizing gauges, strictly proportional to the Rate of Flow or Loss of Head. Mercury Float or Water Operated. Types for gauging Loss of Head, Rate of Flow, Depth, Elevation, Sand Expansion, etc. All Simplex Gauges are designed for accuracy, visibility, accessibility of moving parts, and reliability in service.

BULLETIN 170

AIR RELEASE VALVE

Automatically vents air obstructions that might otherwise cause operating loss or damage to pipe lines and pumps. Dependable in service. Simple construction—one lever movement operates a tight seating needle valve, actuated by a heavy glass ball float. Types for pressures up to 1250 lbs. per sq. in. — tested to several times the service working pressure.

BULLETIN 58

MO & MS METERS • CONTROLLERS • GAUGES • SAND EXPANSION INDICATORS • AIR RELEASE VALVES • AIR & VACUUM VALVES • PITOT EQUIPMENT • SUMMATORS • PRIMARY DEVICES (VENTURI TUBES, PITOT TUBES, ORIFICES, NOZZLES, WEIRS AND FLUMES)

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BAILEY METER COMPANY LIMITED, Montreal, Canada

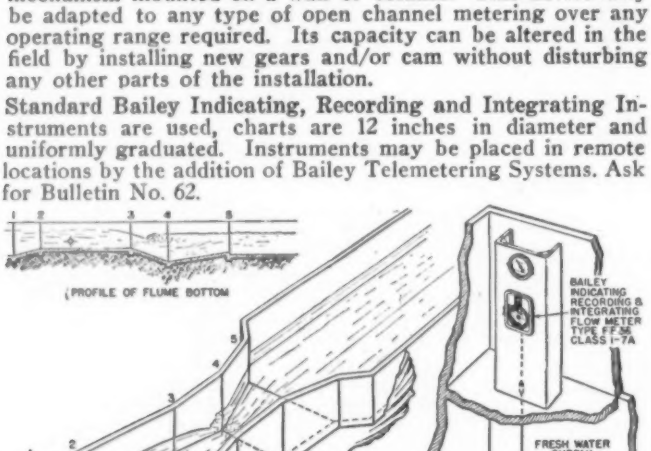
METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

Bailey Flume Meter—Simplicity of installation, low head losses and self-cleaning features of the Parshall Flume have resulted in a greatly increased use of this device for a measurement of Sewage Flow in open channels.

The Bailey Flume Meter is simple and accurate. As shown in the illustration, it consists of a single float which is connected by a flexible cable to the sturdy recording, integrating and indicating mechanism on the panel board. The panel board may be omitted if desired and the recording mechanism mounted on a wall or column. This device may be adapted to any type of open channel metering over any operating range required. Its capacity can be altered in the field by installing new gears and/or cam without disturbing any other parts of the installation.

Standard Bailey Indicating, Recording and Integrating Instruments are used, charts are 12 inches in diameter and uniformly graduated. Instruments may be placed in remote locations by the addition of Bailey Telemetering Systems. Ask for Bulletin No. 62.


PROFILE OF FLUME BOTTOM
BAILEY INDICATING RECORDING & INTEGRATING FLOW METER TYPE FF-M CLASS I-7A
FRESH WATER SUPPLY
FLOAT TUBE
DRAIN

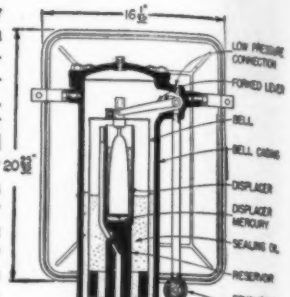
Typical installation of Bailey Flow Meter for Parshall Venturi Flume.

Bailey Weir Meter—For measuring flow using any type of Weir notch, highly accurate results can be obtained with a Bailey Weir Meter. This meter is similar to the Bailey Flume Meter and possesses the same features of sturdiness, flexibility and accuracy. Remote transmission can be provided when desired.

Open Float Type Meter—The Bailey Float Type Meter is especially adapted to measure the flow of sewage, sludge, dirty water or other liquids in pipe lines using a Venturi Tube, flow nozzle or eccentric orifice.

This meter is operated through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes. It is similar in external appearance to the Bailey Flume Meter.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey Register previously described. Remote recorders may be provided by Bailey Telemetering Systems which operate electrically on alternating current.



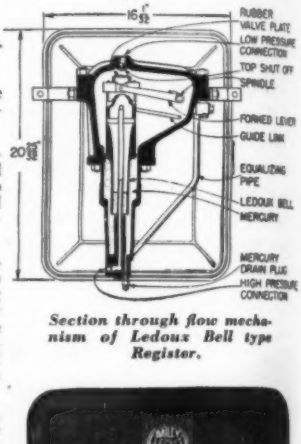
Section through flow mechanism of Air Meter

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Described in bulletin No. 301-A.

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 88-in. of water. *Described in bulletin No.* 301A.



Section through flow mechanism of Ledoux Bell type Register.

Remote Registers — Bailey Telemetering Systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi Tubes and other prmiary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey Gages and Registers.

Bailey control is fully automatic, dependable and exceptionally flexible.

Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

MAIN-LINE METERING OF WATER, SEWAGE AND SLUDGE

By ROBERT T. REGESTER
Consulting Engineer, Baltimore, Md.

AN accurate and convenient means for metering the flow of water in main pipe lines presented an unsolved problem in early American hydraulic and water supply practice. It was not until 1887 that Clemens Herschel, eminent New England engineer, conceived the idea of applying the Venturi principle as a practical method of flow measurement. After conducting elaborate experiments, he invented and successfully calibrated a compound conical tube which he named the "Venturi meter." In 1891 the meter was first installed by the East Jersey Water Company. Its success was immediate and marked a notable contribution to hydraulic engineering. Twelve years later, the first Venturi meter for the measurement of sewage was installed in a large discharge pipe at the Ward Street Pumping Station of the Boston sewerage system. This installation was also successful and continues in operation today.

Since these first applications, continuous developments and improvements have been made in Venturi metering, particularly with regard to automatic registering and recording instruments. Today Venturi meters and their related devices are used throughout the world in both water works and sewerage systems for a variety of purposes. They are recognized as invaluable aids to the efficient operation and control of modern water purification plants and sewage treatment works. Although other metering elements are available, the Venturi meter is the universal standard for the measurement of water, sewage and sludge flowing through main pipe lines.

Venturi Tubes

A standard Venturi tube, as shown in Figure 1, comprises a cylindrical inlet, a converging inlet cone, an intermediate "throat" section and a diverging outlet cone. The inlet cone has a rather

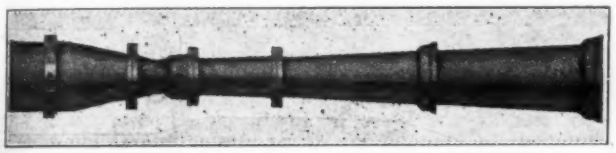


Fig. 1—The Herschel Standard Venturi Tube

steep taper while the outlet cone tapers more gradually. The interior passageway of the tube is entirely unobstructed. The sections of these tubes are usually made of cast iron with throat part bronze-lined to resist corrosion. The inlet and outlet cones are occasionally constructed of either reinforced concrete or steel plates. At both the inlet and the throat of each tube, an annular pressure chamber communicates with the interior by means of numerous small and equally-spaced vent holes. These annual chambers are basically important features of Venturi tubes. The essential purpose of each chamber is to average the pressure head at several points around the tube's circumference, thus avoiding the inaccuracies otherwise introduced by using a single-vent piezometer.

The favorable hydraulic properties of the standard Venturi tube are unequalled by any other type of metering device for main pipe lines. If piezometers are inserted along a standard Venturi tube, the hydraulic grade line will follow the curve as illustrated in Fig. 2. The velocity of flow rapidly accelerates from the inlet to the throat, and thereafter gradually decelerates through the outlet cone. Accordingly the pressure head which is greatest at the inlet end rapidly decreases to the throat where it is least. This difference in pressure bears a definite relation to the velocity of flow and therefore, the quantitative rate of flow. This function varies approximately as the square of the velocity in the throat. It should be particularly noted that the pressure is gradually regained as the velocity decreases in the outlet cone, until at the outlet end nearly all of the original pressure head has been restored. The overall pressure drop, or "friction loss," between the inlet and outlet ends is relatively small for normal rates of discharge, and for low rates it is negligible.

The size of a Venturi tube is expressed by the diameter of the inlet and outlet ends, in inches, which usually is the same nominal diameter as the pipe line for which the tube is intended. The standard tube of Herschel proportions has an average length of about nine inlet diameters, but the exact length depends upon the throat diameter. For installations where the conditions are favorable, shorter and somewhat less costly Venturi tubes are available. In general, these are similar in construction to the standard tubes, but have outlet cones of sharper taper with consequent greater friction loss. Certain special designs of tubes are also made, such as elliptical, constant-acceleration and flat-invert (or eccentric type). In instances where low points cannot be readily drained, or where overhead clearances are very limited, the flat-invert tube may be desirable. However, such tubes are considerably more costly than standard concentric tubes, which experience has demonstrated to be most suitable for normal installations.

For the measurement of sewage and sludge, Venturi tubes require certain special appurtenances. At the inlet and throat pressure chambers, vent-cleaning valves are necessary so that, at intervals, the vents can be cleaned of deposits and the pressure chambers flushed. An individual hand valve is often provided for each vent. However, a recent device (Fig. 3) is available for simultaneously actuating all of the vent-cleaning valves by the operation of a single water- or air-pressure supply valve. Hand holes near the inlet and the throat are useful for an occasional inspection of the interior surface of a tube. In cases where the sewage contains corrosive industrial wastes, a special split-flange section of tube can be provided to expose the entire throat part for examination and cleaning.

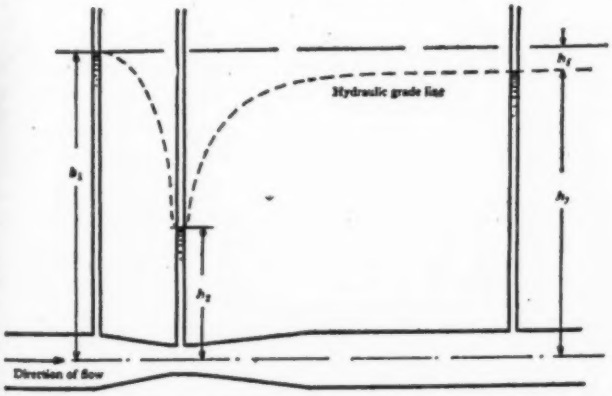


Fig. 2—Hydraulic Grade Line for Flow Through a Venturi Tube

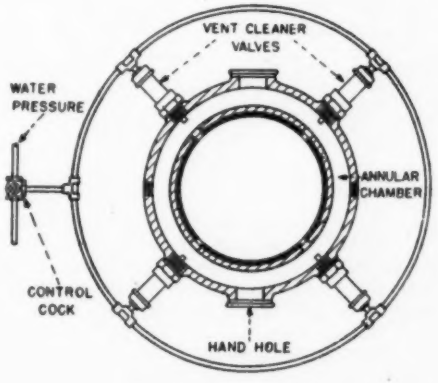


Fig. 3—Hydraulic Vent Cleaning Assembly for Simultaneous Operation

Other Types of Meters

Orifices and Nozzles

Among other types of meters available for main pipe lines are orifices and flow nozzles. Orifices can be obtained in several forms, the most familiar of which is a circular opening in a flat plate clamped between a pair of flanges in the pipe line. The hole of the orifice may be either concentric or eccentric in the flat-plate type. Piezometer connections are made on each side of the orifice plate by tapping two small tubes into the main pipe line. The differential pressure between the inlet and outlet sides of the plate is used to actuate the metering instrument. Orifice plate assemblies with annual pressure chambers, tapped for piezometer connections, are available.

The hydraulic grade line for a plate orifice is shown in Fig. 4. With flow through the main pipe, the pressure head drops abruptly at the orifice and continues to decrease slightly opposite the plane of greatest contraction just downstream from the plate. Beyond this plane the pressure then increases with partial recovery of the original pressure head. Because of the plate projection inside the pipe considerable turbulence results; hence the overall

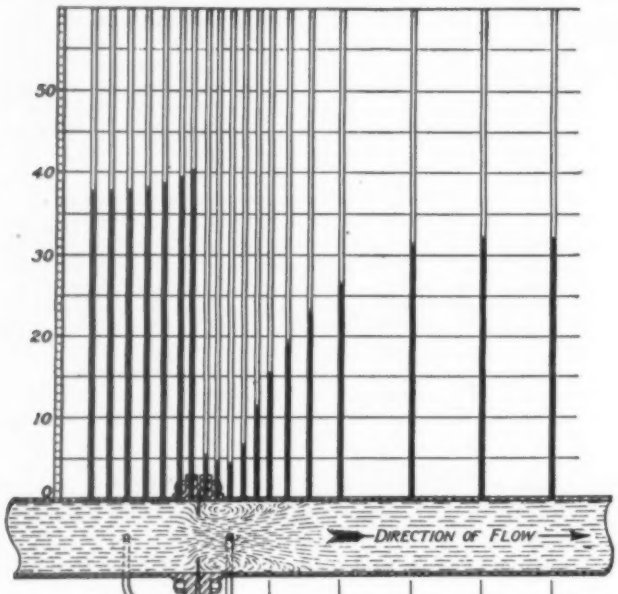


Fig. 4—Hydraulic Grade Line for Flow Through a Concrete Plate Orifice

friction loss for a given ratio of orifice and pipe diameters is much greater than for a Venturi tube having the same ratio of throat and inlet diameters.

If used for the measurement of sewage and sludge, plain orifice meters may be subject to inaccuracies resulting from erosion of the edge and accumulation of solid matter at the projection. Certain specially shaped orifices, or so-called "flow nozzles," resembling Venturi tubes can be furnished to overcome some of the disadvantages of the plate orifice.

The Kennison Nozzle

The Kennison open-flow nozzle is suitable for measuring flows of sewage, industrial wastes and sludge in partially filled pipes and open channels. This nozzle is bolted to the outlet end of a main pipe line with free discharge. The design utilizes the inlet depth produced by a specially shaped outlet for the rate-of-flow function which varies directly with the head. At the inlet of the nozzle, a connection is made to a float tube for operating the metering instrument, Fig. 5. Kennison nozzles are made in inlet sizes varying from 6 in. to 36 in. diameter. Another type of nozzle for partly filled pipes utilizes the discharge-angle relation, produced by a vane which receives the discharge impact, as the rate-of-flow function. This latter nozzle (Schofield) has a parabolic outlet.

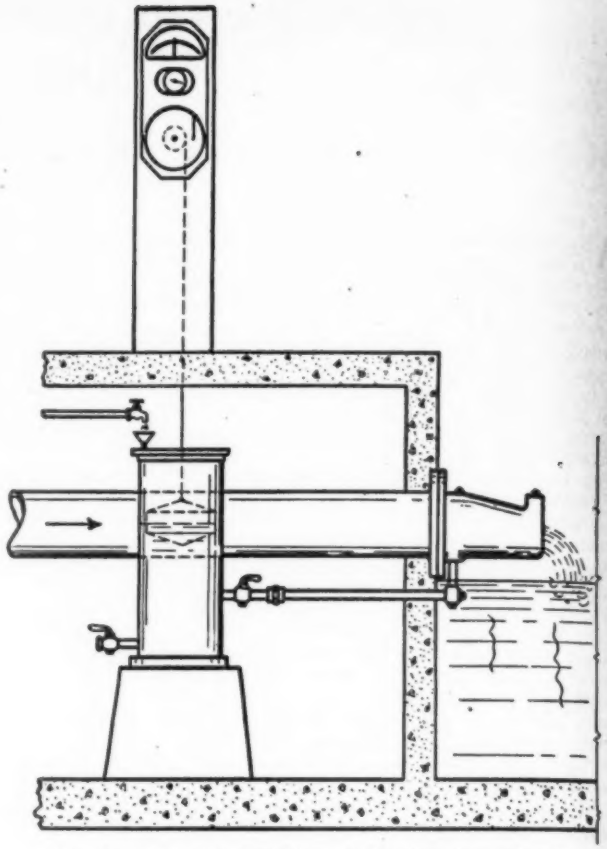


Fig. 5—Typical Installation of the Kennison Nozzle

The Parshall Flume

For the measurement of sewage flows in open channels, the Parshall flume is now extensively used. This Venturi shaped flume usually operates as a free-flow device and therefore requires the use of a single pressure head to accurately determine the discharge rate. The flume was originally developed and is widely used in the West for irrigation purposes. The first important installation for measuring sewage was at Providence, R. I., in 1931, where a large flume having a capacity of 120 M.g.d. with throat width of 10 ft. (Fig. 6) meters the effluent from the sewage treatment plant. An important characteristic of the Parshall flume is the relatively small loss of head, which is about one-fourth that of the standard weir for free flows. This flume is adaptable for both large and small plants and has been calibrated for a variety of sizes and corresponding capacities. A pipe connection is made on the tapering inlet side of the flume for the float actuation of a metering instrument.

Discharge Coefficients and Friction Losses

With any type of meter for main pipe lines, the accuracy of measurements must be supported by exact knowledge of the discharge coefficient and its relation to the size, ratio and other characteristics of the respective type. The accuracy of the Venturi meter has been established through numerous carefully conducted calibration tests by hydraulic laboratories and prominent manufacturers. Such tests have demonstrated that the high initial accuracy of the Venturi meter remains unimpaired during years of continuous service. Coefficient curves for standard Venturi tubes (as made by Builders Iron Foundry and the Simplex Valve & Meter Co.) are available in the A. S. M. E. —Fluid Meters Research Publication, Part I, 1937. In addition thereto, various types of upstream disturbances have been analyzed with regard to Venturi tubes and corrective vanes have been studied by Prof. W. S. Pardoe (Trans. A. S. M. E.—Nov., 1936, and Nov., 1937). Also, a valuable study of the proper application of piezometer connections to metering devices was made by Messrs. Allen and Hooper (Trans. A. S. M. E.—1931) as a further contribution toward meter accuracy.

The overall friction loss produced by a differential metering device in main pipe lines is frequently of economic importance. Such losses may substantially increase annual pumping costs, or may materially decrease the gravity head which is available for

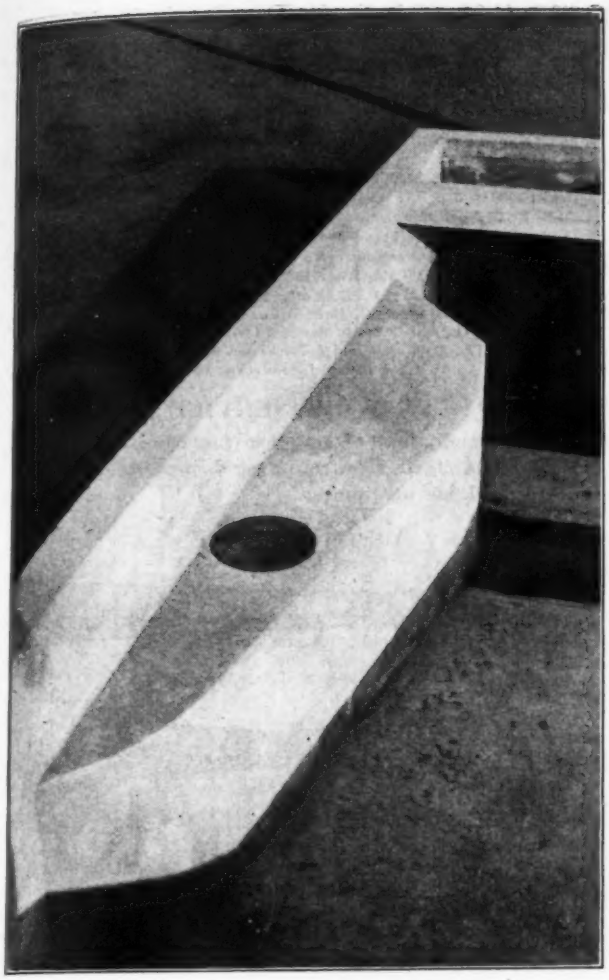


Fig. 6—One-Half of the Parshall Flume, Looking Downstream to Throat Section—Providence, R. I.

other essential purposes in both water purification and sewage treatment plants. This latter condition may involve greater construction costs due to the lowering of structures to meet the resulting hydraulic grade lines. In either case, a small initial saving in the price of an unsuitable meter may be insignificant in comparsison with the ultimate cost incurred by excessive fraction loss. Accordingly, that metering device in which the recovery of inlet pressure head is the greatest will most likely prove to be the most economical selection.

The accompanying diagram, Fig. 7, strikingly presents a comparison of the recovery characteristics and friction losses for a standard Venturi tube of Herschel proportions, a short Venturi (S4) tube, two types of flow nozzles (NS and N) and an orifice plate. These data are expressed thereon as precentages of the differential head for various ratios of throat and inlet diameters. For the frequently used ratio—0.5, it should be noted particularly that the corresponding friction loss for an orifice is about seven times the loss for a Herschel standard tube.

Herschel standard Venturi tubes have a fraction loss of only 10% to 15% of the differential head for a ratio of 0.25 to 0.75—throat to inlet diameter. In comparison, the fraction loss for orifices is much greater and varies from 49% to 92% of the differential for the same ratio range of orifice opening to pipe diameter.

Venturi Metering Instruments

A variety of instruments for the measurement of water and sewage in connection with Venturi tubes and other differential metering devices is available. Each type is actuated by the differential head, either by direct connection or by some medium of transmission such as air or electricity. Several types of instruments are illustrated in Fig. 8 and 9. The mechanism of one prominent type is shown in Fig. 10. At the rear of the register two large mercury wells, connected at the bottom to form a U-tube, receive the differential pressure from the Venturi

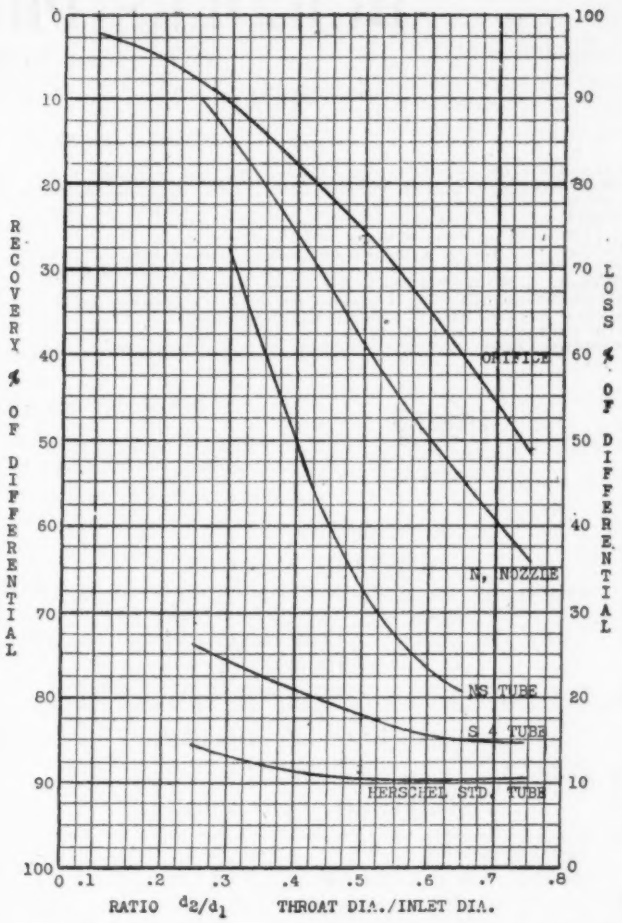


Fig 7—Recovery Characteristics and Friction Losses of Various Differential Producers

For Figs. 8 and 9, see next page.

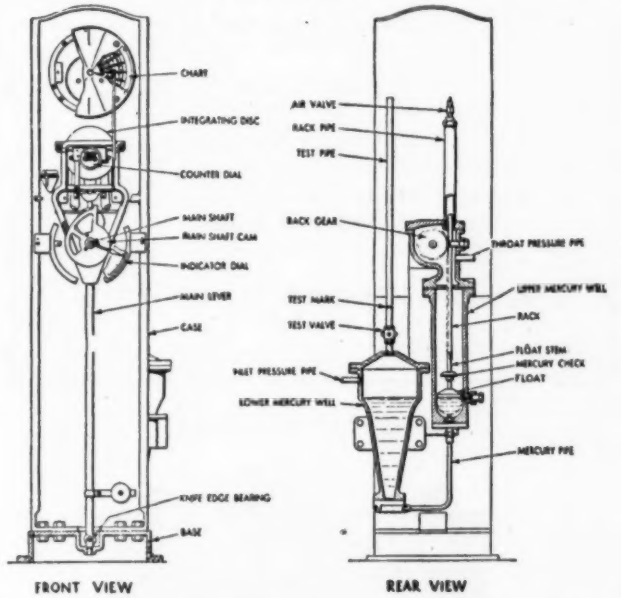


Fig. 10—One Example of the Pressure Chamber Type of Register Mechanism, with Rack and Gear Transmission of the Float Movement

tube through small pipes from the inlet and the throat. One of the mercury columns supports a solid metal float of large diameter, which is responsive to minute variations in mercury levels. Through a positive rack and gear transmission, the float

(*Continued on Page R-34*)

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Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed Bulletins, illustrating and describing equipment mentioned in these pages, are available on request.

VENTURI METERS

Metering the Flow of Water, Sewage, Sludge, or Air through Main Pipe Lines.

TYPE M, FLO-WATCH AND CHRONOFLO INSTRUMENTS

Metering the Flow of Water, Sewage, Sludge, Gas, or Air through Medium Sized and Small Lines, Open Channels, etc.

PROPELOFLO METERS

Totalizing flow meters of propeller type for main water line metering.

SIGHTFLO INDICATORS

Constant head-loss, variable area meters for water and sewage works applications.

HOOK LIGHT SAND EXPANSION GAUGE

Inexpensive, portable. Measures sand expansion with a light.

VENTURI CONTROLLERS

Effluent Rate, Wash Rate, Raw Sewage and Return Sewage.

FILTER GAUGES

Loss of Head, Rate of Flow, and Sand Expansion.

LIQUID LEVEL GAUGES

Settling Tanks, Filters, Clear Wells, Wash Tanks, Reservoirs, etc.

RATIO GAUGES

Air/Sludge and Return Sludge/Sewage.

KENNISON NOZZLES

Metering Open Flow of Sewage, Sludge and Trade Wastes.

CHRONOFLO TELEMETERS AND CONTROLLERS

Flow, Liquid Level, Pressure, Temperature, and Chemical Feed Proportioning.

TOLEDO-CHRONOFLO CONVEYOR SCALES

Weighing Sludge Cake in Transit.

VENTURI TUBES

Fig. 1—Herschel Standard Venturi Tube

Fig. 2—VTS4 Venturi Tube

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of the Venturi Tube (Figs. 1 and 2) installed in pipe line, and the Register-Indicator-Recorder or other instruments connected to the Tube by two small pressure pipes. The proportions and length of the Herschel Standard Venturi Tubes were selected by the inventor from extensive experimentation and are designed for a minimum pressure loss. This usually has a definite economic value since it lowers pumping costs. The VTS4 Venturi Tubes are shorter, somewhat lower in price, but throats are not as interchangeable and pressure loss is somewhat greater. Bulletin 143-B.

TYPE M REGISTER-INDICATOR-RECORDER

Fig. 3—Type M Register-Indicator-Recorder

A popular instrument having the advantage of unusual sturdiness, durability, and accuracy; furnishes three distinct kinds of information: an indication of the momentary flow through the Venturi Tube; a permanent record of this rate shown upon a 12" circular chart; the total quantity on a 3½" counter dial; all dials graduated in direct reading units for the particular Venturi Tube with which it is to be used. Bulletin 324-A.

FLO-WATCH

Fig. 4—Flo-Watch Totalizer-Indicator-Recorder

A small, medium-priced mechanical instrument universally applicable for use with Venturi Tubes, Nozzles, Orifice Plates, and Weirs: available in a variety of mountings and dial combinations. Bulletin 318-B.

PROPELOFLO METER

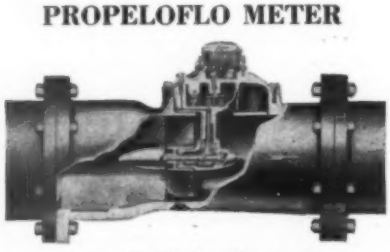


Fig. 5—Propelofio Meter flange mounted. Available also in saddle mounting and bell and spigot models

This improved propeller-type flow meter for main water line metering introduces many new features including streamline Venturi design. A self-contained unit easily installed; registers total flow directly in gallons. Accurate throughout wide range; low loss of head; low first cost and upkeep. Bulletin 350.

BAROMETRIC MERCURY MANOMETER

Model MAB is a simple, yet accurate, flow rate indicator with scale graduated directly in flow units; used with any type differential producer. Bulletin 343.

VENTURI FILTER CONTROLLER

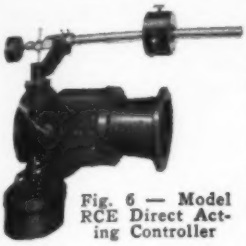


Fig. 6 — Model RCE Direct Acting Controller

Since Builders manufactured the first Venturi Filter Controller many years ago, Venturi Controllers have become standard equipment in filtration plants. Several types of controllers are offered, each type designed to serve particular conditions, automatically maintaining constant flow rate through the filter bed.

THE MODEL RCE DIRECT ACTING CONTROLLER

(Fig. 6) Features smooth, unwavering control; low loss of head; sturdy, balanced valve; compact design; powerful "floating piston" actuation and exclusive molded tapered piston seal. All rotating bearings of the Model RCE Controller are antifriction bearings. Bulletin 321-A.

THE MODELS RCA AND RCB CONTROLLERS

Hydraulically operated. Model RCA has a control valve of the gate type with specially shaped port; Model RCB has a two-butterfly valve and is used on larger effluent lines. Bulletin 325.

WASH WATER CONTROLLERS, MANUAL MASTER CONTROLLERS and CLEARWELL MASTER CONTROLLERS also are available—information on request.

FILTER GAUGES

Fig. 7—Rate of Flow and Loss of Head Gauge

Builders Filter Gauges are the result of nearly a half-century's experience in designing and manufacturing such instruments for hundreds of plants. Reduced to simplest mechanical elements, these gauges are styled and finished to enhance the attractiveness of modern filtration plant interiors. Bulletin 329.

RATE OF FLOW AND LOSS OF HEAD GAUGES are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display information, gathered by the accurate, dependable Builders Diaphragm Pendulum Units, have earned emphatic approval of water works engineers after more than a decade of service under all sorts of conditions.

WATER LEVEL GAUGES, operated by spherical copper float in a pipe or well, are used for indicating and/or recording water level in basins, tanks, and reservoirs. Indicator dials and charts are graduated to read in feet of depth, elevation or other units.

Fig. 8—Large Dial Gauge

BUILDERS LARGE DIAL ILLUMINATED GAUGES, available in 24" and 30" sizes with single or double faces for wall or ceiling mounting, are commonly used in water works to make readings visible to the operator from a distance. Concealed double hinges, a patented feature, allow access to the mechanism without removal from mounting. Indirect white gas-tube illumination gives a pleasing soft glow uniformly around entire dial circumference.

HOOK LIGHT SAND EXPANSION GAUGE

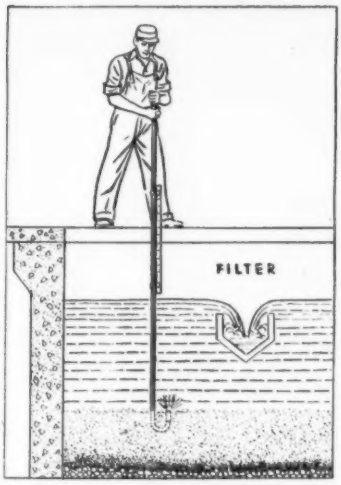


Fig. 9—Method of using Hook Light Sand Expansion Gauge

A novel and accurate means for determining sand expansion with a light during back washing of filter beds. Amount of expansion is read directly on scale without reference to water temperature or size of sand grains; duplicate readings within 1/16" can be consistently obtained. The Hook Light is inexpensive and entirely portable. Bulletin 348.

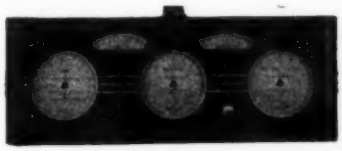


Fig. 10—Five-Dial Ratio Gauge

RATIO INDICATING GAUGES are especially useful in sewage plant operation and enable operators to maintain predetermined ratio of flow rates between air/sewage, air/sludge, etc. Bulletin 329.

KENNISON NOZZLES

Accurately measure flow through partially filled pipes and open channels where there is wide range in flow rates. This device is particularly successful on measurement of raw sewage, sludge and trade waste; availale in size 6" to 36". Bulletin 334-A.

Fig. 11—Kennison Nozzle for Open Flow

CHRONOFLO TELEMETERS

Fig. 12—Chronoflo Receiver

Since their introduction a decade ago, Chronoflo Telemeters have found broad application in water and sewage plant service in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflow Transmitter.

SIGHTFLO FLUSHING WATER INDICATOR

A rate of flow instrument designed as a guide in maintaining normal flushing rates. The Indicator is a constant head-loss variable area meter and indicates at a glance the flow of clear water into the taps or annular chambers of differential-operated Meters. Bulletin 347.

Fig. 13—Sightflo Flushing Water Indicator

For Fig. 10, see preceding page.

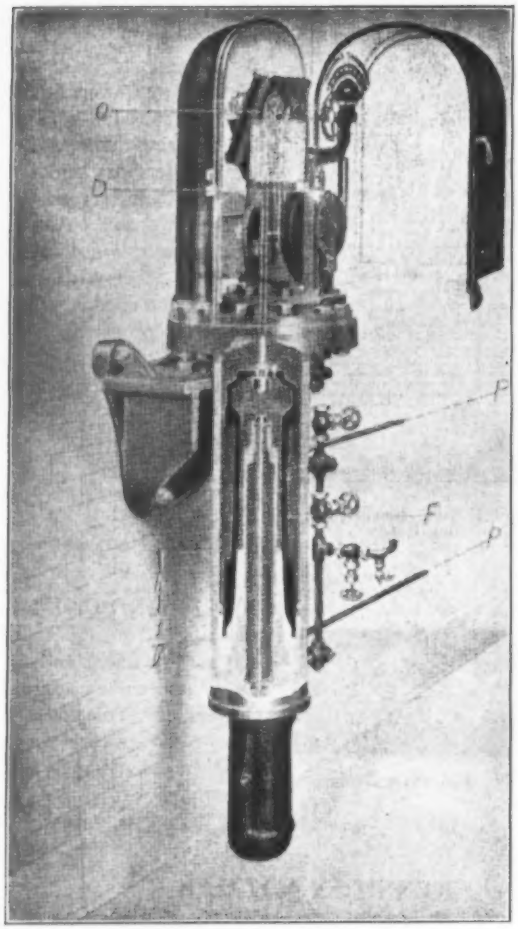


Fig. 8—Pressure Chamber Type of Instrument Using Mercury Sealed Bell (Courtesy of Simplex Valve & Meter Co.)

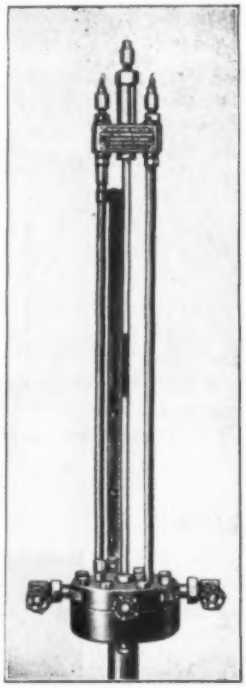


Fig. 11—Portable Flow-Rate Indicating Instrument of the Barometric Type

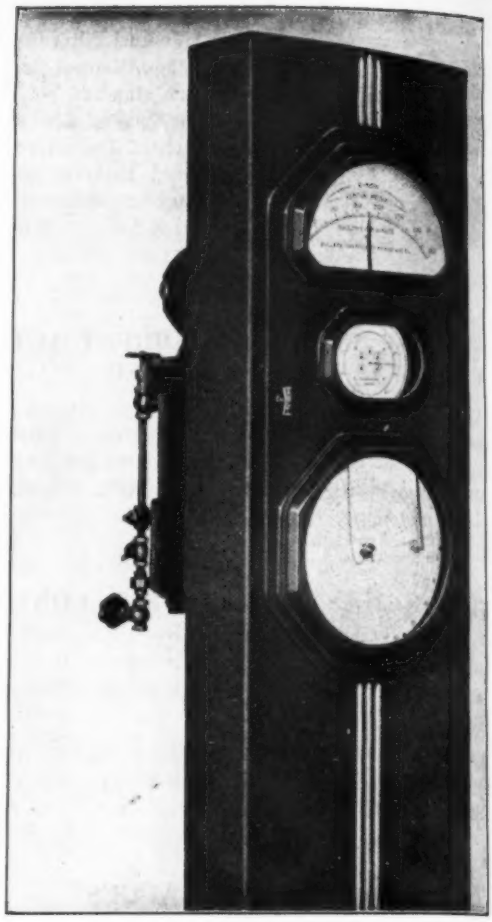


Fig. 9—Modern Register-Indicator-Recorder, with Pair of U-Tube Mercury Wells (Courtesy of Builders Iron Foundry)

movement establishes the position of the rate-of-flow indicating hand, the rate recording chart pen and the driving roller of the motor-driven totalizer. These are respectively the upper, lower and middle dials (Fig. 9).

A simple mechanical instrument, suitable for main pipes in small plants and for less important pipes in large plants, is very similar to the instrument shown in Fig. 13. This instrument can be used with either Venturi tubes or orifices for the measurement of water, sewage, sludge, air and other fluids. Principal features of this device are compact design, gear-driven integrator and universal mounting for floor, wall or panel.

A portable and sturdy flow-rate indicating instrument of the barometric type is shown in Fig. 11. The rate scale, 22 in. long, can be graduated to read directly in units of flow. The slightest change in rate through the Venturi tube, or other differential producer, will cause an immediate and relatively large response in the vertical movement of the mercury column within the single glass tube. In addition to this instrument, several types of manometers can be obtained for a variety of purposes. A double-tube type is especially suitable for general testing work. Graduations can be either in inches of deflection, or directly in rates of flow.

Where the conditions of installation make the use of mechanically actuated instruments impracticable, electrically-operated transmitters with receiving instruments can be employed for remote metering indications and recordings. Numerous types or systems have been developed such as time impulse, stepped resistance, self-synchronous motor pairs and others.

The time impulse system is used with Chronoflo transmitter and receiver instruments, Fig. 12 and 13. The transmitter receives the differential pressure, and is usually installed close to the Venturi tube or other differential device. It contains a mercury float, a synchronous motor-driven mechanism and a magnetic mercury switch. These elements are so interconnected that for a portion of each cycle (¼ to 1 minute), varying in duration in exact proportion to the rate of flow, electrical "time impulses" are sent to the distant receiving instrument. The latter, through motor-driven magnetic clutch elements, translates these impulses into flow units on the dial and chart.

Weather-proof instruments for installation out of doors are readily available with substantial weather-proof metal housings.

Metering instruments are logical sources of signal and control actions as related to flow rates. Lights, sound apparatus, power relay switches and other electrical elements can be readily actuated by such instruments at relatively small cost.

Methods of Installation

Two simple methods of installing Venturi tubes and instruments for the measurement of water are shown—Fig. 14. That for medium and high heads is on the left, and the method for low heads on the right. When the pressure is ten pounds or

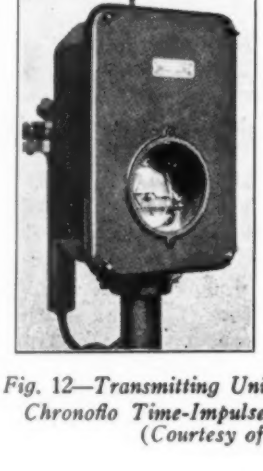


Fig. 12—Transmitting Unit

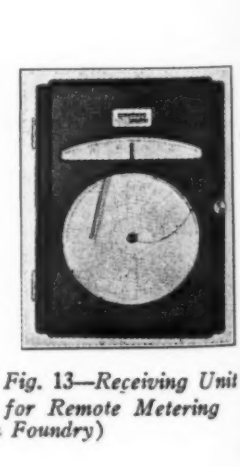


Fig. 13—Receiving Unit

Chronoflo Time-Impulse Instruments for Remote Metering (Courtesy of Builders Iron Foundry)

more at the floor where the instrument is located, two small pressure pipes—one from the inlet and the other from the throat of the tube—form a direct connection. These pipes can be several hundred feet in length. Where the acting hydraulic head is low (e.g. raw water supply to filter beds) the usual mercury wells at the back of the registering instrument are

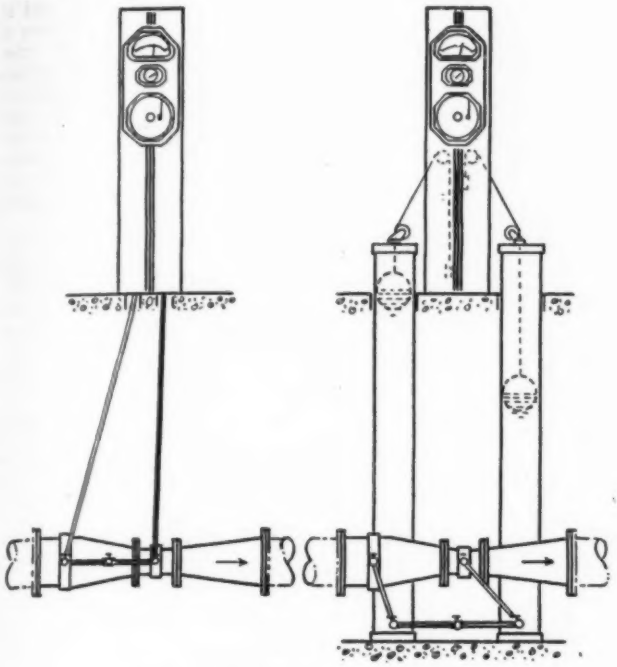


Fig. 14—Venturi Meter Installations
Left—For Medium and High Heads
Right—With Float Tubes for Low Heads

removed and vertical inlet and throat float tubes are substituted. Cables from these floats lead to a differential actuating mechanism at the back of the instrument.

Other types of installation require the mercury wells to be placed at a low elevation with a cable connection to the register above. With any of these types for the measurement of sewage and sludge, provision must be made for seals to prevent deposits from reaching the registering instrument through pressure connections, or for proper flushing with clean water. Such flushing may be either continuous or manually regulated, as the requirements dictate.

Air Relay System

The use of compressed air as a medium for the transmission of the inlet and throat pressures of a Venturi tube, or other differential producer, to a distant recording instrument is frequently advantageous. One type of "air relay system" employs two diaphragm units, one directly connected to the inlet and the other to the throat of the Venturi tube. Each unit consists (Fig. 15) of a hollow chamber (C) which is divided into two compartments by a solid rubber and fabric diaphragm (D). The inner side of the diaphragm is subjected to the liquid pressure from the tube; the outer side receives an external air pressure to balance the liquid pressure on the inner side. Air is continually vented through a throttled needle valve (N) attached to the diaphragm unit. Two small pipes, one from the inlet and the other from the throat relay unit, are connected from the outer compartments to the usual mercury wells at the rear of the registering instrument. The transmitted air pressures are exactly equal, respectively, to the actual inlet and throat pressure heads in the Venturi tube.

This type of unit forms a seal between the tube and the instrument, which is especially important in metering sewage and sludge. In the measurement of sludge, unless it is "thin," it is necessary to provide continuous water flushing through appropriate small sight-feed orifices.

Another well known type of air relay system operates with a single air pressure which is proportional to the amount of the liquid differential pressure.

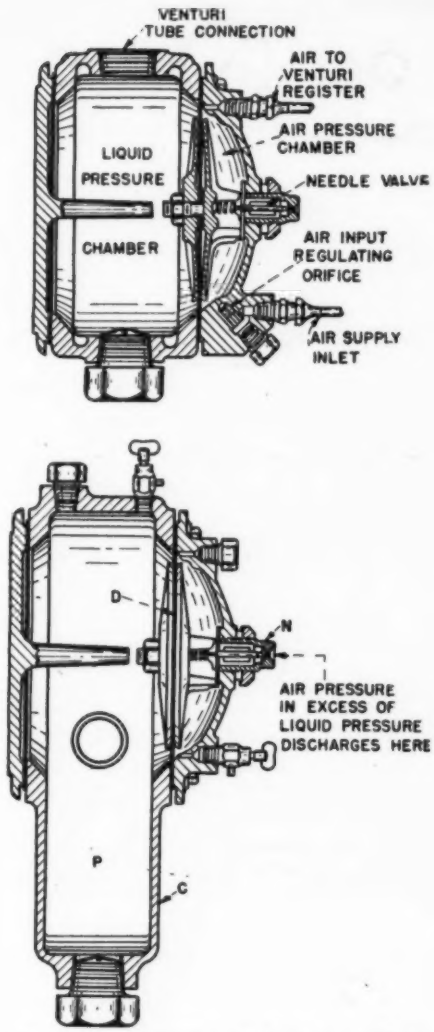


Fig. 15—Diaphragm Unit for Air-Relay System

Flow Summation

Recent developments make it possible to summarize, on a individual meters in their respective discharge pipes. It may be single instrument, the readings of several meters. For example, a water works pumping station may have several pumps with desirable to totalize these separate flow rates for purposes of accurately introducing chemicals, such as chlorine, without wastage. In this case, an electrical transmitter (such as Chronoflo) can be attached to each registering instrument (Fig. 16). The impulses sent out by these transmitters go to a master unit which integrates the respective values, and then transmits the total to distant summation indicating, recording and totalizing instruments, as required.

In sewerage districts and sewage treatment plants, the summation principle can be utilized to great advantage. Sewage flows from scattered communities can be summarized and transmitted to the central or joint treatment plant for the guidance of the operator, and for the allocation of operating charges. Likewise, flow divisions within a large sewage plant can be summarized for control purposes.

Means can also be provided to give the difference in readings for two meters, or the difference of the combined rates of flow in groups of meters.

Special Metering Instruments

The marked trend in recent years of centralized control in water purification and sewage treatment has been accompanied by a fulfilled demand for the broader performance of main pipeline meters. Distant transmission by air or electricity to centralized panels and control tables, the ratio of one flow to another, the summation of flows to one or more central dials, the automatic

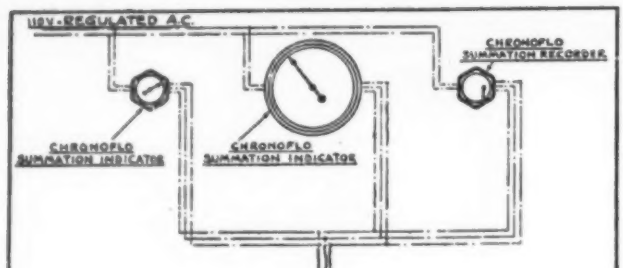


Fig. 16—Diagrammatic Arrangement of Flow Summation Instruments for Cermak Station, Chicago

controls of flows and distant pumps to maintain perdetermined levels or rates, the proportioning of chemical dosages to main flows and other functions, are examples of modern metering requirements. The design and finish of the instruments themselves have been "modernized" to harmonize with the present architectural attractiveness of plant interiors. Effective illumination has been likewise provided for single- and double-faced master indicating gauges, frequently of large diameter.

A flow and ratio gauge for each unit in a modern activiated sludge plant is illustrated, Fig. 17. There are five dials, the three largest showing (left to right) rates of air flow, sewage flow and return sludge flow to an aeration tank. The two smaller dials show (left) the ratio of air to sewage—in cu. ft. per gal., and (right) the ratio of return sludge to sewage—in per cent of sewage flow. In addition, there is an automatic control knob for pre-setting the latter ratio for any desired value. A pair of these five-dial gauges are mounted on one control table similar to those used in water filter plants.

Installation Requirements

To insure the proper application of metering equipment, specific data should always be obtained from the meter manufacturer for a particular installation. However, in general, certain standard requirements are noteworthy.

The Venturi tube should preferably be preceded by a straight length of pipe having the same diameter as the tube; this length being at least six times the tube diameter up to 24 in. and at least 12 ft. for larger sizes. Where space is limited, or there is the probability of turbulent or spiral flow ahead of the tube, straightening vanes may be required. Any kind of fitting may be placed at the outlet end of the tube. Since the centrifugal pump is almost universally used in water works and sewerage systems, pulsations in flow are rarely encountered. However, such condition may occasionally be presented and must receive special consideration. It is essential in making pressure pipe connections that they be run on a continuous grade, avoiding summits or depressions where air or silt may collect.

The Parshall flume must be set at the proper elevation with respect to the channel, preferably so that it can operate at all times under "free flow" conditions, with a limit of 95% submergence. It should be located in a reasonably straight section of channel, where the distribution of flow is fairly uniform. The flume, however, will operate satisfactorily under rather poor approach conditions. The dimensions and proportions of the flume must adhere to the established standards.

In installing the Kennison nozzle, care must be taken to provide proper approach conditions. This device should be preceded by a section of pipe at least eight diameters in length, and the water or sewage must flow smoothly from the nozzle under free discharge. Any conditions of installation which might cause a "shooting velocity" at times, should be corrected by the use of proper fittings upstream.

Orifice plates are more sensitive to approach conditions than Venturi tubes, and require a straight length of smooth pipe both upstream and downstream from the plate. For the upstream, the length required may vary from five to thirty diameters, while for the downstream length—up to eight diameters, depending upon the piping layout and the diameter ratio. Straightening vanes may be required to eliminate swirls, cross currents and eddies; their use may make it possible to shorten the necessary lengths of pipe as just mentioned.

Conclusion

Certain fundamentals of main line metering and some of the modern developments in metering equipment have been briefly discussed. Emphasis is placed upon the importance of regarding each meter installation as an engineering problem, which requires the consideration and advice of experienced manufacturers. Low cost equipment may properly serve for relatively unimportant work, but is entirely unsuitable for checking the daily performance of main units and for controlling the efficiency of treatment processes. In general, the highest grade of equipment as offered by prominent manufacturers cost only a small fraction of the total construction contract on important projects. Obviously, the best is the wisest selection.

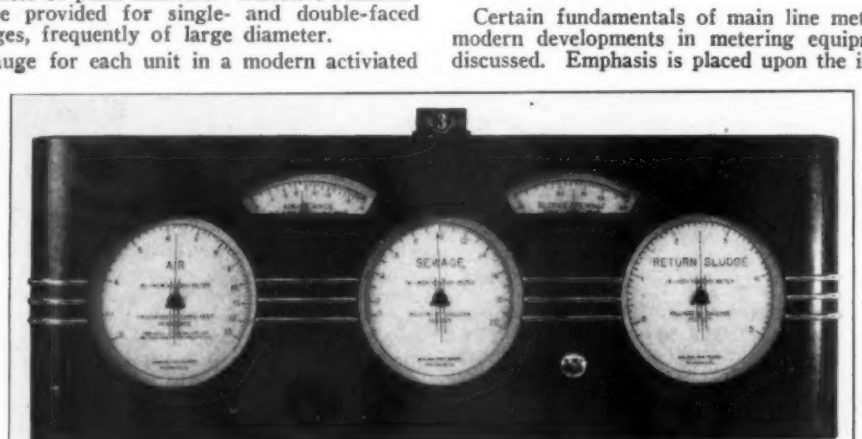


Fig. 17—Special Flow and Ratio Gauge for Modern Activated Sludge Plant, Baltimore, Md.

PROPELLER-TYPE METERS

For Main-Line Metering

JAMES M. MONTGOMERY, Consulting Engineer*
Los Angeles, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for over thirty years. During the past fifteen years this same current meter principle has been applied as a primary element for the measurement of main-line flows by R. W. Sparling, of Los Angeles, and has proven itself well suited for this purpose.

The Propeller-Meter

The propeller-type meter, as illustrated in Figure I, is made up of a six-bladed propeller approximately eight-tenths of the pipe diameter mounted transversely in the center of the pipe. The propeller is made of a plastic material, having a specific gravity of approximately one, and is suitable for use in either cold water or hot water up to 300° F. The propeller practically displaces its own weight in water and is mounted on ball bearings which allow it to rotate freely in the stream of water.

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of one-half linear foot per second. The index, or the number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Characteristics

The current metering principle has certain characteristics that make it particularly well adapted for main-line measurement, as the action of the propeller is solely dependent upon the velocity of flow in the line. The pressure requirement is only such as to always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6" and larger does not exceed six (6) inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section and a propeller free from incrustation. The plastic propeller has proven itself well suited for this purpose as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted in either a cast-iron or steel tube having a bronze liner.

Installation

The metering element may be installed directly on existing pipe lines by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined. In all installations the meterhead may be removed from the pipe line very quickly and easily and it is normally good practice in sizes 12" and smaller to make a yearly inspection and sizes 16" and larger, every five years.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiralling or jet action, is required for accurate results. The spiralling effect that may be caused in a flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use but a very simple and effective correction may be made by the installation of three vanes — each approximately one-third the pipe diameter and two and one-half pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially open gate-valve, but are effective for double elbows or other standard fittings and with such vanes the meter element may be installed with but two pipe diameters of straight approach.

One pipe diameter downstream is normally sufficient for all installations. Unless approximately ten pipe diameters are available ahead of the meter, it is always good practice to use the straightening vanes. When the metering element is installed complete, with either a flange or bell and spigot tube, the three vanes mounted directly inside this metering section constitutes a complete unit ready for installation.

The metering element can be installed in either a vertical or horizontal pipe line and is suitable for mounting on either the suction or discharge side of a centrifugal pump.

Compound Design

Figure II is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. A range of 150 to 1 is possible. A compound unit consists chiefly of two propeller-type meters working in series

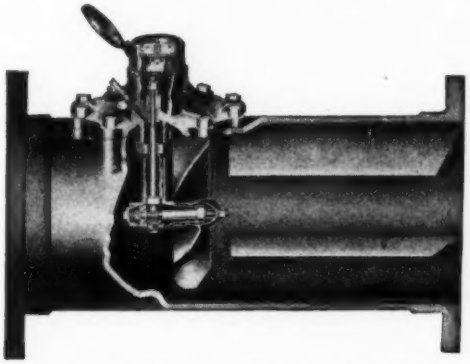


Fig. I—Cutaway View of Propeller Meter Note the flow straightening vanes in the tube, the whole unit ready for insertion as a single piece in the main-line.

through a pair of rachet clutches, allowing the meter revolving at the highest speed to drive the totalizing register. On the very low flows the large meter will under-register and thus allow the small meter to drive the totalizer. As the flows increase a pipe velocity is reached where the large meter has come into step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

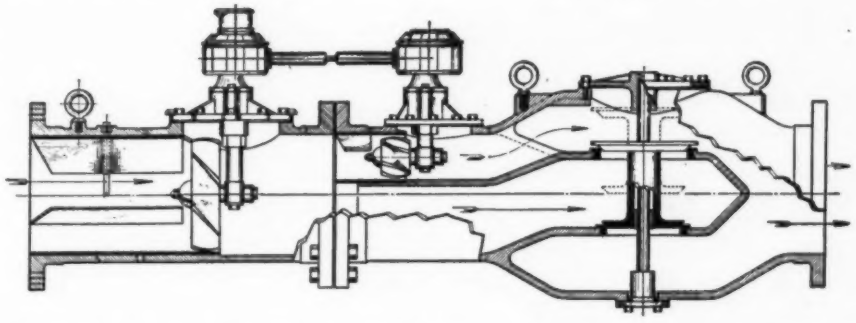


Fig. II—Section Through Propeller-Type Compound Meter Note valve which closes on low flows to cause entire flow to pass through small meter.

Although the minimum flow is considerably above that of the standard domestic compound meter it is well adapted for main-line measurement as the pressure loss caused by the entire unit does not normally exceed two pounds at maximum flow.

*President, J. M. Montgomery & Co., Engineer.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

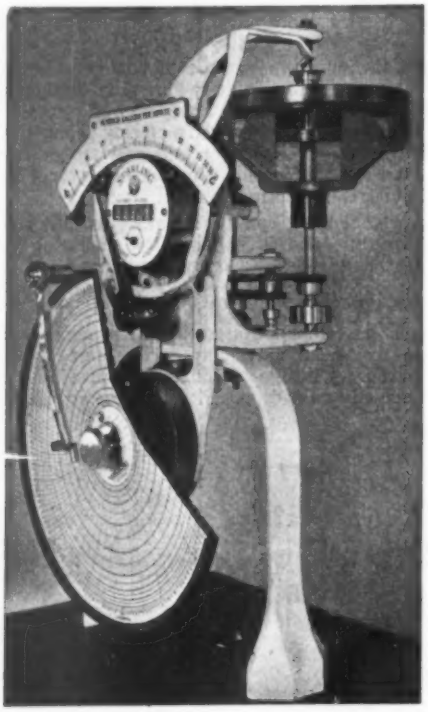


Fig. III—Typical Sparling Indicator-Recorder of the Mercury Governor Type.

Figure III illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extremely simple and well suited for normal pump like measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Application in Chemical Feed Control

Automatic control of chemical feeders by either mechanical or electrical means is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the periodic inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the waterworks field.

The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless it has passed through a filter bed. Care must also be taken when installing such meters on raw water gravity lines that screens are provided at the inlet structure to prevent excessive algae or weeds from passing down the pipe and stalling the meter propeller.

WHERE THE WATER DOLLAR GOES

Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill.

It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.

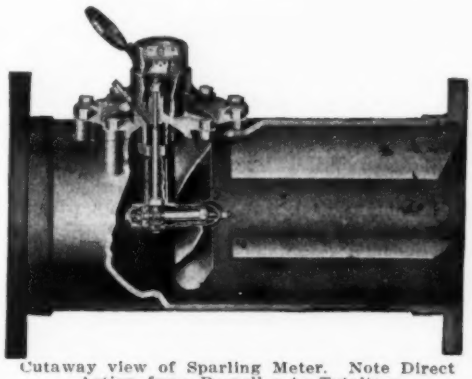
R. W. SPARLING

MANUFACTURER OF

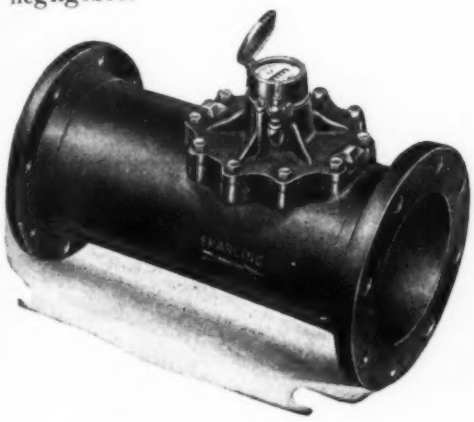
MAIN-LINE WATER MEASURING EQUIPMENT

Box 3277, Terminal Annex, LOS ANGELES 54 — 3104 S. Michigan Avenue, CHICAGO 16
622 Broadway, CINCINNATI 2 — 101 Park Avenue, NEW YORK 17 — 6 Beacon Street, BOSTON 8

TOTALIZATION is the primary step in all Sparling Main-line Meters. Within its rated range, each rotation of the propeller marks the passage of a definite quantity of water. The revolutions are registered at the totalizer in the unit quantities desired. Each meter is tested against volumetric tank measurement and is guaranteed to be accurate within 2 per cent. Loss of head pressure is negligible.

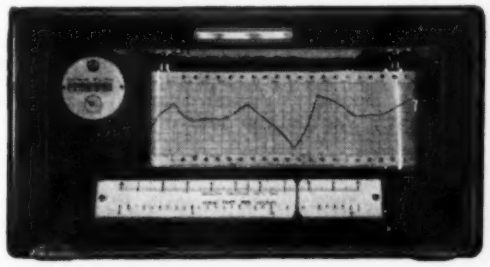


Cutaway view of Sparling Meter. Note Direct Action from Propeller to Totalizer

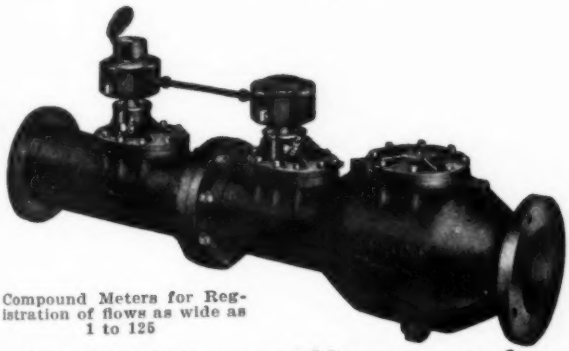


The meterhead may be saddle-mounted on the pipe, or is installed as a tube section, as shown. Saddle type meters, 2-inch to 72-inch; screw-tube meters, 2-inch to 6-inch; flanged tubes 2-inch to 36-inch; bell and spigot tubes, 4-inch to 36-inch. Compound Meters from 6″ x 2″ to 36″ x 10″.

Flow-rate indicators and recorders are added if, as, and when, required. They are mechanically controlled within 15 feet of the meter, or electrically controlled at any distance. Instruments may be Pedestal, Wall or Panel mounted.



Above is a differential type recorder, with straight-reading, 60-day strip roll chart. These operate electrically at any distance from the meter. The scale is equally calibrated in two flow equivalents.



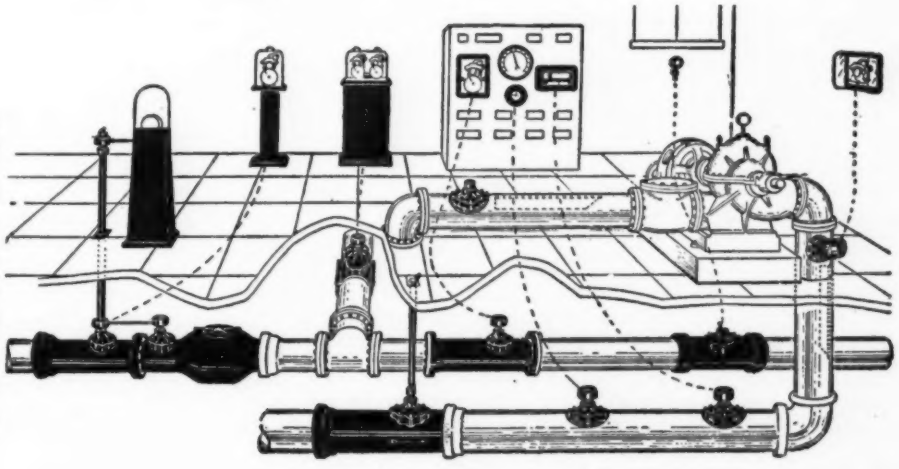
Compound Meters for Registration of flows as wide as 1 to 125

SPARLING Compound Meters measure flows over ranges as wide as 1 to 125. There is no sharp cut-over point and pressure loss is the lowest of any compound meter.

Autometered controls with Sparling Meters are used in water treatment plants, pulp and paper mills, steel mills and many industries, for proportional sampling and chemical feeding.

Typical Pumping Station Installations

Sparling Meters may be installed on the suction or discharge side of the pump, in vertical or horizontal position. Note at left of sketch, a Bell & Spigot Compound Meter with remote recorder and solid extension controlling chlorinator. A saddle mounted meter on wood or transite pipe is also shown. For further details, see Bulletin No. 308, sent upon request.



NOMOGRAPHIC CHART FOR FLOW IN PIPES

Full and Partly Full

By H. M. GIFFT

Asst. Prof., Cornell University, Ithaca, N. Y.

PRACTICALLY all flow problems can be solved by using either of two general equations, $V = CR^xS^y$ and $Q = AV$, or a combination of the two. Manning's formula, $V = \frac{1.486}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$ is probably more practical for an algebraic solution and is used extensively for open channel problems. The Hazen-Williams formula, $V = 1.318CR^{0.63}S^{0.54}$, is commonly used for flow in pipes under pressure. Because of the odd exponential functions, solution is ordinarily by alinement charts or logarithmic graphs.

The most common type of alinement chart is constructed for one friction coefficient and consists of parallel scales for the four variables Q, D, S and V, where Q = quantity, D = diameter of the pipe, S = slope of pipe, and V = velocity of flow. If the scales are located properly in relation to each other, solution may be had by a single alinement of a straightedge between any two unknowns to find the other two. Often two S scales are constructed on opposite sides of the line to provide for two possible friction factors. Such charts are found in most texts on water supply, sewerage, and hydraulics.

Sometimes it is desirable to solve problems for other values of C, in which case it is necessary to provide a pivot line along with the five variables Q, D, V, S and C. Most charts which appear in various hydraulics texts and handbooks include only four variables, and the fifth is obtained by solving the simple equation, $Q = AV$. All five variables, however, can be included, and by a proper arrangement of scales and pivot line it is possible to construct a chart to solve all full pipe flow problems.

Such a chart appears herewith. The solution of ordinary problems by this chart is quite simple. Since there are five variables and only two independent equations, $Q = AV$ and $V = 1.318CR^{0.63}S^{0.54}$, three of the quantities must be known or assumed. An alinement of a straightedge is made between any of the two variables on the *same* side of the pivot line. The straightedge is then pivoted to the third known quantity on the *other* side of the pivot line and the desired quantities read.

Solving Simple Pipe Flow Problems

Example I. Assume that a sewer to carry 10 cfs., when flowing full but not under pressure, is to be laid on a grade of 0.1 per cent. To determine the required diameter of pipe and the resulting velocity of flow if the C is assumed to be 100.

A straightedge is lined between C = 100 and S = 0.001 and the point of intersection with the pivot line is located. The straightedge is then pivoted about this point to Q = 10 cfs.; the diameter of 28.5 in. and the velocity of 2.25 ft. per sec. are read on the appropriate scales.

Example II. To determine the loss of head in a 24-in. water main carrying 20 cfs. if C = 120.

The straightedge is lined between Q = 20 cfs. and D = 24-in., and the point of intersection located on the pivot line. (The velocity is noted to be 6.5 ft. per sec.) The straightedge is then pivoted to C = 120 and the loss of head is 6.3 ft./1000.

Application of Chart to Equivalent Pipe Problems

Various other problems can be solved by a proper use of the chart. For example, in water distribution design it is sometimes desirable to determine the size of pipe which would be equivalent to several other pipes acting in parallel. If the pipes are all of the same length, any convenient point may be chosen on the pivot line and the discharges corresponding to the various sizes determined by successive alinements of the straightedge from the single point on the pivot line. The equivalent pipe will be found by alinement of the straightedge between the same point on the pivot line and a quantity equal to the summation of the individual quantities already determined.

Example III. To determine the size of a single pipe equivalent to 12-in., 10-in., and 8-in pipes all of the same length and acting in parallel. Any point is assumed on the pivot line, say where Q_1 = 40 gpm. and D = 12-in. Then, holding this same pivot point, for D = 10-in., Q_2 = 25 gpm., and for D = 8-in., Q_3 = 14 gpm. Then for $Q = Q_1 + Q_2 + Q_3$ = 79 gpm., the equivalent pipe is 15.5 in. in diameter.

In case the given pipes are not of the same length, a total loss of head must be assumed and corrected to the loss of head per thousand feet for each of the pipes. From any single value of C and the computed three losses of head, three points are located on the pivot line. From these three points and the corresponding diameters, first Q_1, Q_2 and Q_3 are determined and the equivalent pipe is found as above.

Determination of Friction Coefficient

The resistance to flow in a water main may increase over a period of years. This change may be due to a change in the surface characteristics or a reduction in effective cross section due to deposition in the pipe. Thompson[1] has shown that flow characteristic of a length of main may be determined rather simply by a series of pressure measurements and a single measured flow from a hydrant. A detailed description of the test appears in the original article.

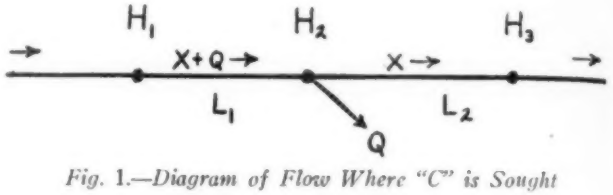


Fig. 1.—Diagram of Flow Where "C" is Sought

Assume a certain quantity of water, Q, is drawn from a hydrant and the corresponding pressure heads determined at points on either side of and at the hydrant, these pressure heads being represented by H_1, H_2, and H_3. Then $\frac{H_1 - H_2}{L_1} = S_1$ represents the loss of head per foot for the length above the hydrant and $\frac{H_2 - H_3}{L_2} = S_2$ represents the loss of head below the hydrant. (See Fig. 1.)

Letting X represent the flow in the pipe in addition to the measured quantity, Q, then

$$\frac{X+Q}{A} = 1.318\ CR^{0.63}\ S_1^{0.54}$$

and

$$\frac{X}{A} = 1.318\ CR^{0.63}\ S_2^{0.54}$$

from which

$$Q = 1.318\ ACR^{0.63}\ (S_1^{0.54} - S_2^{0.54})$$

or

$$C = \frac{Q}{16.55D^{2.63}\ (S_1^{0.54} - S_2^{0.54})}$$

This equation can easily be solved by means of the chart and the special scale of S and $S^{0.54}$ at the bottom thereof. S_1 and S_2 are converted to $S_1^{0.54}$ and $S_2^{0.54}$ and the results subtracted to give $(S')^{0.54}$. Then $(S')^{0.54}$ is converted to S′ and this value is used on the nomographic chart to determine C.

Example IV. Pressure head measurements at the three points are H_1 = 91.2 ft., H_2 = 83.6 ft., and H_3 = 80.7 ft. when the quantity, Q, being drawn is 0.5 cfs. The size of the main is 12-in., L_1 = 500 ft. and L_2 = 470 ft.

$$\frac{H_1 - H_2}{L_1} = \frac{91.2 - 83.6}{500} = 0.0152 = S_1$$

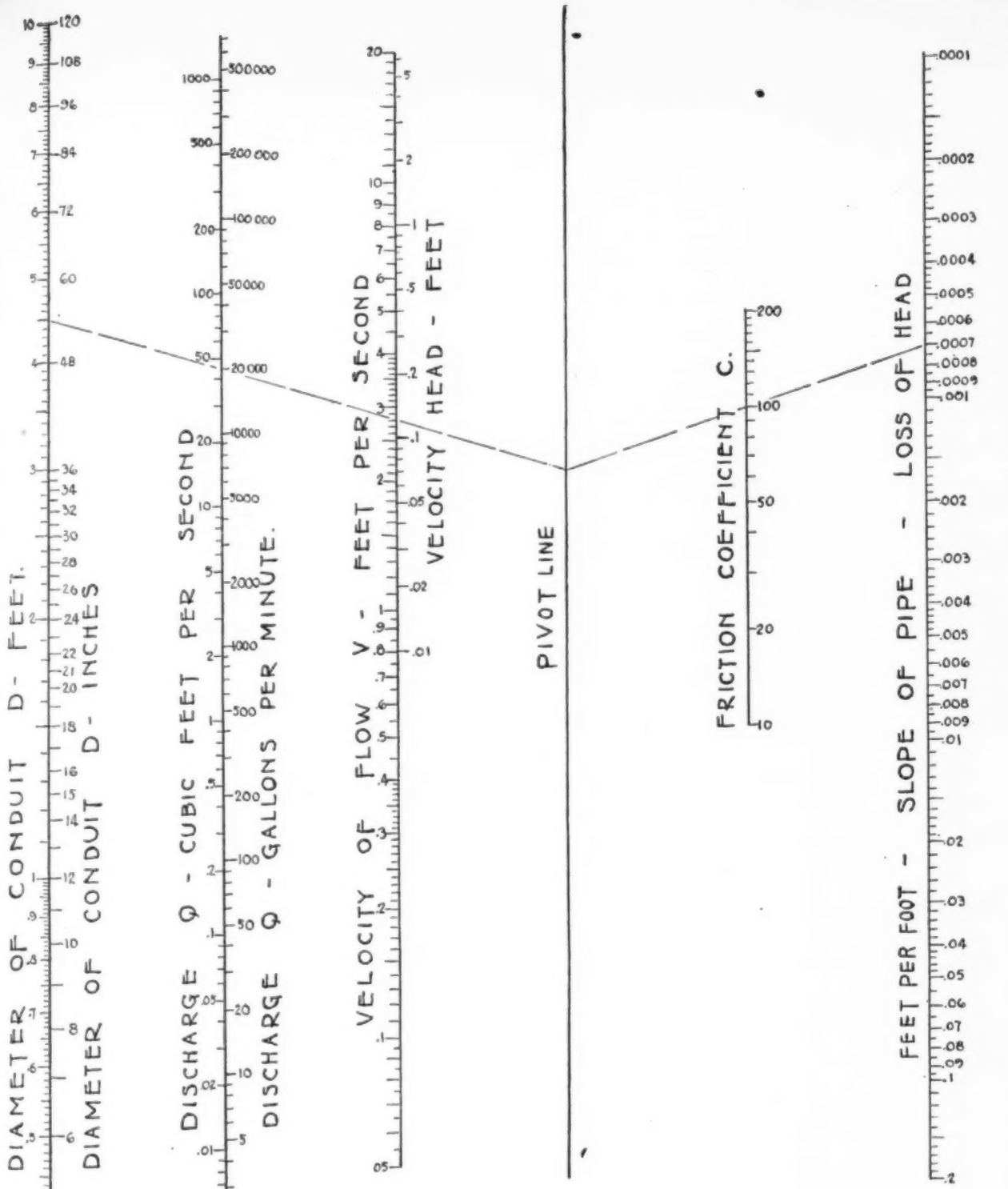
and $S_1^{0.54}$ from the special scale is 0.105.

$$\frac{H_2 - H_3}{L_2} = \frac{83.6 - 80.7}{470} = 0.0063 = S_2$$

and $S_2^{0.54} = 0.063$. Then $S_1^{0.54} - S_2^{0.54} = 0.042$ and $S' = 0.0024$.

To determine C, line the straightedge between Q = 0.5 cfs. and D = 12-in., and locate the point of intersection on the pivot line. Then lining the straightedge between the point on the pivot line

[1]Thompson, R. E., Resistance Coefficient Calculation from Incremental Flow Measurement Jour. AWWA. 36, 163, Feb., 1944.


DIAMETER OF CONDUIT D - FEET.
DIAMETER OF CONDUIT D - INCHES
DISCHARGE Q - CUBIC FEET PER SECOND
DISCHARGE Q - GALLONS PER MINUTE.
VELOCITY OF FLOW V - FEET PER SECOND
VELOCITY HEAD - FEET
PIVOT LINE
FRICTION COEFFICIENT C.
FEET PER FOOT - SLOPE OF PIPE - LOSS OF HEAD

NOMOGRAPHIC CHART

FLOW OF WATER IN PIPES

HAZEN-WILLIAMS FORMULA

$V = 1.318 C R^{0.63} S^{0.54}$ $\quad Q = AV$

$Q = 16.55 C R^{2.63} S^{0.54}$

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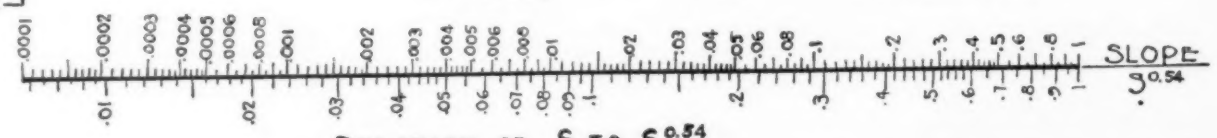

RELATION OF S TO $S^{0.54}$

and $S' = .0024$ on the loss of head scale, the intersection on the C scale is 29.

The increased resistance to flow may be shown in another way by determining the approximate effective diameter of the pipe. For the above conditions, the straightedge is lined between C = 100 and $S' = .0024$ on the slope scale and a point of intersection located on the pivot line. Then pivoting about this line to Q = 0.5 cfs., the intersection on the D scale shows a diameter of 7.8 inches, indicating incrustations on the inside of the pipe approximately 2.1 inches in thickness.

To determine the approximate value of X (the flow in addition to the measured Q), the straightedge is lined between C = 100 and $S = \frac{H_2 - H_3}{L_2} = .0062$ to a point on the pivot line. Then pivoting to the estimated effective diameter of pipe, 7.8 inches, as previously found, X is 0.9 cfs.

It should be remembered that the pressure heads must be determined with reference to the same datum plane. If the mains at the three points of pressure determination are not at the same elevation, the differences in elevation above the lowest point must be added to the pressure heads determined by the pressure gauge readings.

Application of Chart to Pipes Flowing Partly Full

Theoretically, when a pipe is flowing half full, the velocity V is equal to the velocity when flowing full, V_F, and the discharge Q is half of the full discharge Q_F. A line on the chart between $\frac{Q_F}{2}$ and V_F would also represent the discharge q, the diameter d, the slope s, and the velocity v, of a hypothetical pipe flowing full and having a slope of 1.5 times the slope S of the pipe being considered.

From $V = 1.318\ CR^{0.63}\ S^{0.54}$ and $Q = AV$, by eliminating R and A, we obtain

$$Q = 5.25\ \frac{V^{2.16}}{C^{1.16}\ S^{1.72}}$$

from which may be written $\frac{q}{Q_F} = \left(\frac{V}{V_F}\right)^{2.16} \left(\frac{s}{S}\right)^{1.72}$

Inasmuch as $s = 1.50\ S$ then $\frac{q}{Q_F} = 0.5 \left(\frac{V}{V_F}\right)^{2.16}$

This equation, together with the computed relationship between partially full flows and corresponding velocities, is plotted in Fig. 2. Since the two curves are very close, the corresponding Q and V of the pipe flowing partly full at various depths would be practically equal to the q and v of a series of hypothetical pipes flowing full, and of $s = 1.50S$.

Also from $V = 1.318\ CR^{0.63}S^{0.54}$ and $Q = AV$, by eliminating V we may write $Q = 16.55CR^{2.63}S^{0.54}$.

Then $\frac{q}{Q_F} = \left(\frac{d}{D}\right)^{2.63} \left(\frac{s}{S}\right)^{0.54}$

and inasmuch as $s = 1.50S$, $\frac{q}{Q_F} = 1.25 \left(\frac{d}{D}\right)^{2.63}$

This equation, together with the computed relationships between partial flows and corresponding depths, was also plotted in Fig. 2. Over the range of values from $q = 0.1Q_F$, the d of the series of pipes flowing full is approximately 0.2D greater than the actual depth of the flow in the partly full pipe. Therefore, within these limits, approximate depths of flow can be determined by subtracting 0.2D from the indicated d of the hypothetical pipe. Three examples follow.

Example V. To determine V and depth of flow when D = 30-in., C = 100, S = 0.0006, Q = 2.0 cfs.

From the intersection on the pivot line as determined by lining a straightedge between C = 100 and S = 0.0006, and pivoting to D = 30 in., $Q_F = 8.5$ cfs. and $V_F = 1.75$ ft. per sec. A line from $\frac{Q_F}{2} = 4.25$ to $V_F = 1.75$ intersects the pivot line again. Pivoting about this point to Q = 2.0 cfs., then V = 1.45 ft. per sec.

The depth of flow is 0.20 less than the intercept of 1.33 on the diameter scale. Depth = 1.33 − 0.50 = 0.83 ft. Using the same pivot point, other corresponding values of Q, V, and depth of flow can be obtained.

A simpler solution may be obtained by making the original alignment between C = 100 and $s = 1.5S = 150(0.0006) = .0009$ to determine the pivot point directly. Since this method simplifies the solution and the calculation of 1.5S can be done mentally, this method is preferable.

Example VI. To determine D and minimum slope S, such that V = 1.5 ft. per sec. at minimum flow when $Q_F = 14$ cfs., C = 90, $Q_{min} = 2.1$ cfs.

A straightedge is lined between Q = 2.1 and V = 1.5 to determine a pivot point. Pivoting about this point to $\frac{Q_F}{2} = 7.0$, then $V_F = 1.97$. A straightedge between this $V_F = 1.97$ and $Q_F = 14.0$ yields D = 3.0 ft., and determines a new pivot point. Pivoting about this second point to C = 90, then S = .0073.

Example VII. To determine the slope when D = 6.0 ft., C = 110, Q = 250 cfs., V = 12 ft. per sec.

The straightedge is lined between Q = 250 and V = 12 to locate a pivot point. Pivoting about this point to

$$d = \frac{D}{2} + 0.2D = 4.2 \text{ ft.}$$

on the diameter scale, then $q = 150 = \frac{Q_F}{2}$ and $v = 10.3$ ft. per sec. $= V_F$. Then pivoting around $V_F = 10.3$ to $Q_F = 2 \times 150 = 300$, D = 6.0 ft. (as given) and a new point is determined. Finally pivoting to C = 110, S is found to be .0048.

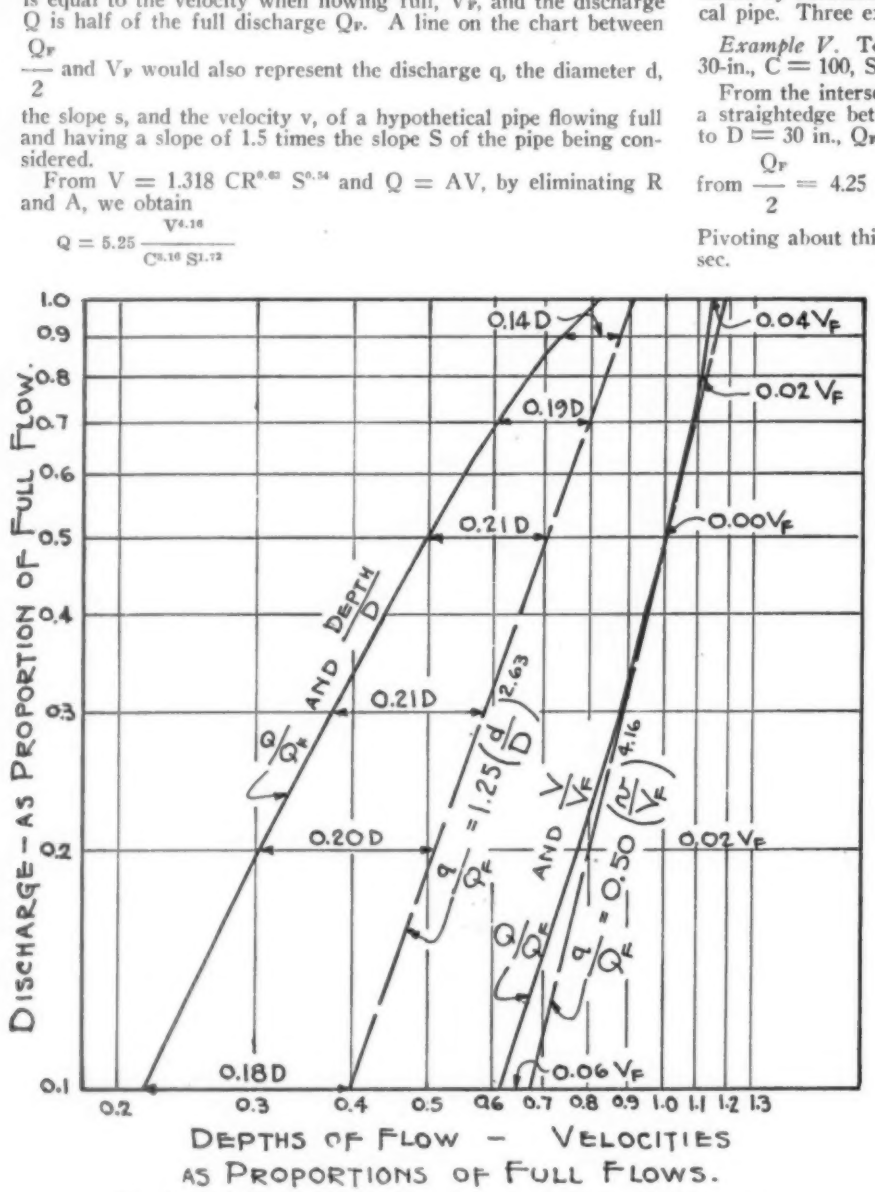

Fig. 2—Relation of Discharge to Depths of Flow and Velocity in Partly Full Pipes
(In terms of proportions of full pipes)

PRACTICAL HYDRAULICS*

By P. S. WILSON†
Glen Ridge, N. J.

I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.
L = Length of the weir crest in feet.
h = Head on the weir in feet.
$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^{3}/^{2}$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

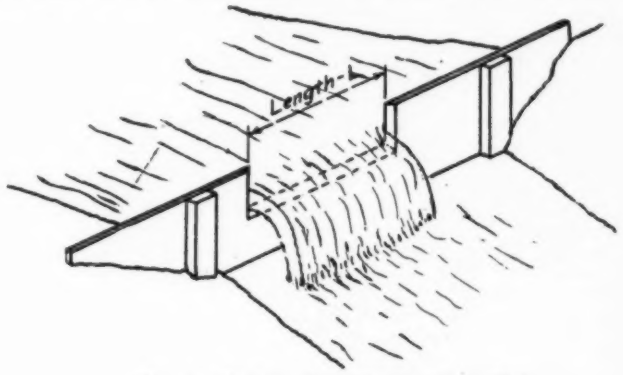

Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

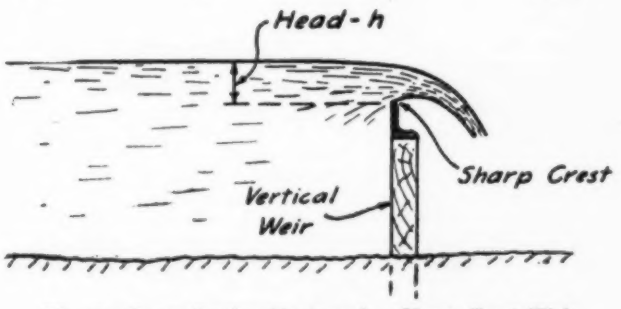

Fig. 2—Cross Section Rectangular Sharp Crest Weir

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II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions.* In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length (3.0 — 0.2) = 2.8 feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which

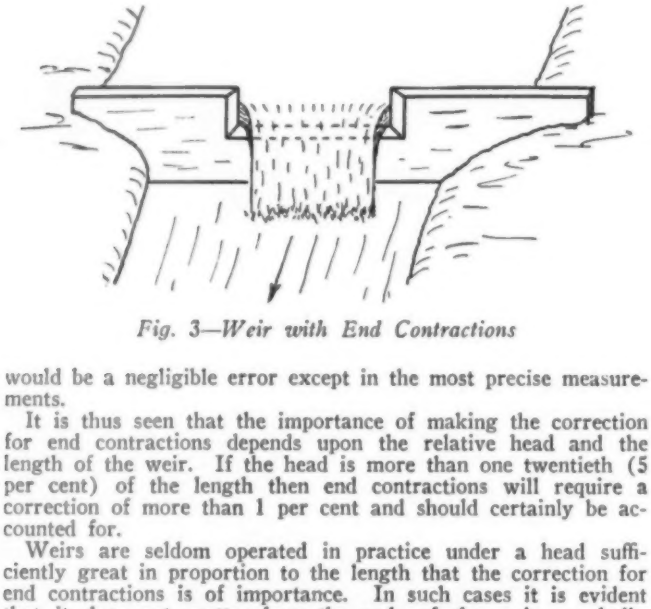


Fig. 3—Weir with End Contractions

would be a negligible error except in the most precise measurements.

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be

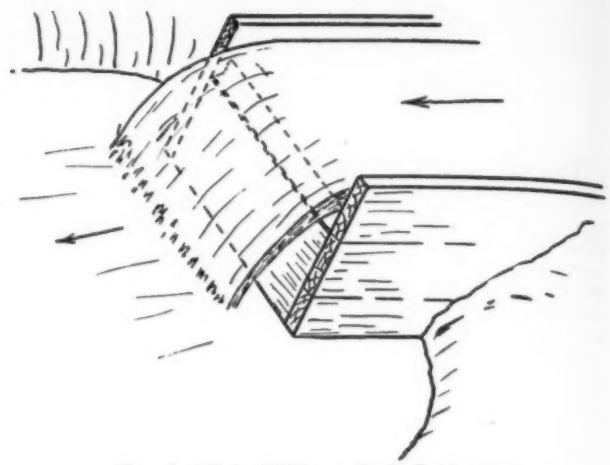


Fig. 4—Weir Without End Contractions

of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

III. Measurement of Head on Weirs

The measurement of flowing water by means of a weir depends in turn upon the measurement of the *head* of water on the weir. Having determined the weir formula to be used, depending upon the design of the weir crest, the presence or absence of end contractions and any other fixed condition, the recorded flow then depends upon the head. The head is the single remaining variable quantity. It is the quantity which is actually observed and measured in the field, the desired knowledge as to the amount of water flowing being then computed by the use of the formula, table or diagram. It is assumed in this discussion that the flow over the weir is not affected by backwater from below.

The head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. Figure 1 is a vertical cross section through a sharp crest weir with water flowing over it under a head indicated by (h). The shape of the upper and lower water surfaces shown in this figure have been determined by measurement and have been found to have forms similar to these, regardless of what the head is, so long as the weir has a sharp crest and a vertical upstream face. Under special conditions at low heads the water may, however, cling to the downstream face of the weir.

Figure 1 shows clearly the fact that in this general case the

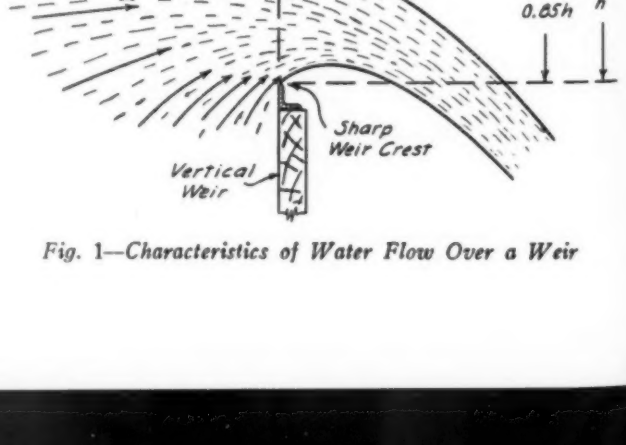


Fig. 1—Characteristics of Water Flow Over a Weir

water only touches the crest along the one sharp edge and then leaps free. The arrows showing the converging stream indicate the reason for the shape which the lower surface of the water is found to take. There is one very important fact to be noted from Figure 1—namely, the upper surface of the water starts to curve downward before it reaches the weir. This results in the depth of water at the weir crest actually being only about 85/100ths of "h" (expressed as 0.85h)—the condition which makes it necessary to measure the height of the water surface at some distance upstream from the weir when determining the head. The height of the water surface should be measured at a point located upstream from the weir *a distance at least equal to three times the maximum head* to be encountered.

Measuring Gages

The type and design of gage to be used to determine the water level depends upon the accuracy desired and the conditions under which it will operate.

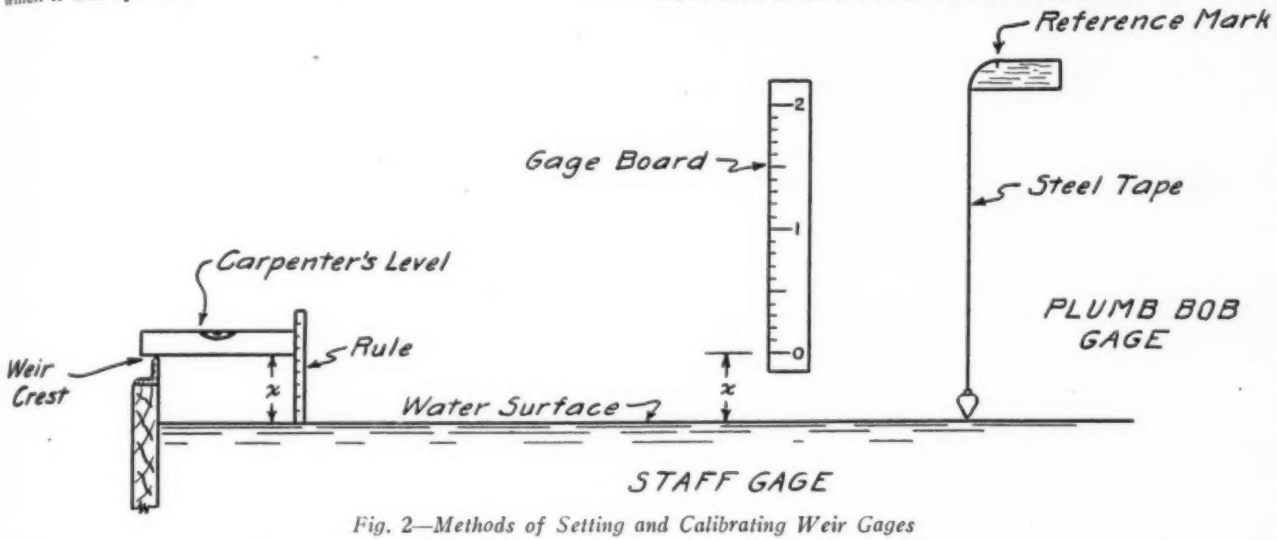


Fig. 2—Methods of Setting and Calibrating Weir Gages

The Staff-Gage

The simplest and most commonly used type of gage consists merely of a strip of wood or metal with the necessary graduations marked upon it. A section of a carpenter's rule or a surveyor's rod may be used if adequately waterproofed by varnishing. One of the best forms of gage board consists of a vitreous enameled ware metal plate mounted on a wood plank. The graduations and figures are baked into the enamel. Gages such as these, often called staff-gages, if well graduated and carefully read will enable the water level to be determined to within about 0.01 feet, equivalent to about ⅛ inch. This is sufficiently accurate for most purposes other than studies requiring laboratory refinements. One of the greatest disadvantages of this type of gage, however, is the necessity for locating the observer's eye near the water level when taking a reading. This is not always convenient. Care must be taken to read at the true water surface and not the height to which the water surface curves upwards where it wets the gage.

When mounting a staff-gage great care is needed to insure that the zero of the gage is exactly level with the crest of the weir and that it remains so. A small error in this respect will cause a large error in the results, particularly at low heads. Moreover, this error will always be in the same direction and will not tend to correct itself or be compensated for by other errors.

By the careful use of a surveyor's level a gage may be set with sufficient accuracy. If a surveyor's level is not available then the water surface itself may be used in the manner indicated in Figure 2. Choose a time when the water surface is not rising or falling too rapidly and preferably when it is lower than the weir crest. By means of a carpenter's hand level and rule measure the distance (x) down to the water surface from the weir crest. Then measure up from the water surface at the gage location and set the gage zero the same distance (x) above the water level as the weir crest was found to be. Then, afterward, such gages should be regularly checked to be certain that they have not been moved, and that the zero point is correct.

Plumb-Bob Gage

Another form of gage is known as a plumb-bob gage. It consists of a graduated steel tape with a heavy plumb bob on its end. It is used to measure from a fixed reference mark, above water level, down to the water surface. By allowing it to swing slightly the contact of the plumb bob with the water surface may be very accurately noted. This naturally assumes the water surface to be smooth. The plumb-bob gage may be most accurately read if the tape is run over a curved block of wood, mounted permanently above the water, which has the reference mark fixed on its upper surface, as indicated in Figure 2. The zero reading on this type of gage may be determined by measuring down to the water surface from the weir crest as shown in Figure 2 and applying the correction factor determined by a simultaneous reading of the tape.

Chain Gage

A similar type of gage known as a chain gage is often used. For the tape a chain running over a wheel is substituted. With this arrangement the position of a marker attached to the chain above the wheel is read along a horizontal scale. This type of gage is not so accurate as the former and it is not advised for weir readings except in the case of rough work or high heads. It is often used for river heights where accuracy within about 0.05 feet is generally satisfactory.

With all types of gages difficulty is introduced if the water level is disturbed by waves or surges. In the case of the gages above described this can only be overcome by the skill and patience of the operator in mentally averaging the indications while observing them over a short period. Practice can develop considerable skill in doing this.

IV. The Float Gage

Probably the most accurate type of gage, if well designed and constructed, is a float gage. Besides its accuracy it also has other advantages. Difficulty in reading due to waves and surges may be most readily overcome with the float type gage which is readily adapted to the use of an automatic recording mechanism. They may be classified into two types. The simplest type consists of the float with a rigid vertical stem attached to and supported by the float, with an index or pointer at its upper end. The gage reading is obtained from the position of this pointer along a fixed vertical scale. In the other type of float gage the motion of the float is transmitted to some form of indicating or recording mechanism by means of a flexible wire or tape.

The Float

A suitable float is the first essential. It must not become water logged, but must retain its buoyancy. To meet this condition a hollow sheet metal float is generally used, and copper is the preferred material because of its resistance to corrosion. The seams must be well locked and thoroughly soldered. Earthenware floats have been used in sewage or other corrosive liquids. Floats are most often made cylindrical with the axis vertical, in order to fit in a float pipe and, for ease of construction. It is important to have the top and bottom dished outward so that the float cannot be weighted with water on top or lifted by air trapped beneath. The float should have at least three vertical fins projecting a half inch or more from its sides in order to prevent it from clinging to the wall of the float pipe or well. Sometimes a spherical float is used, but in that case its weight, or its counterweight, should be adjusted so that it will float near its middle, in order to gain the maximum sensitivity.

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

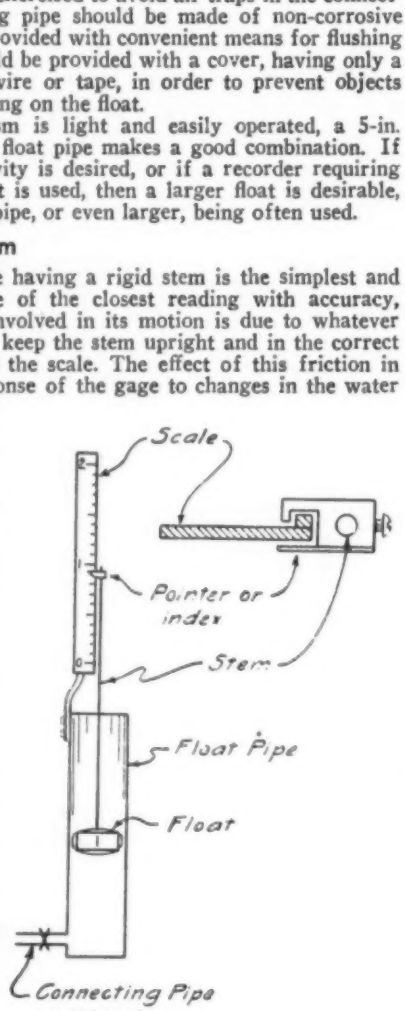


Fig. 1—Float Gage with Stem

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

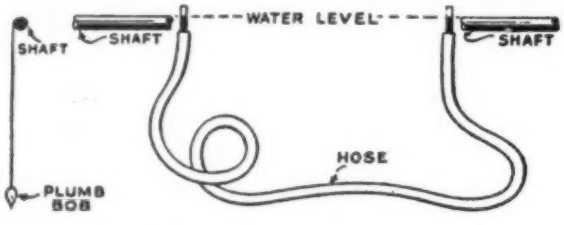
Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

ACCURATE LEVELLING AND ALIGNING BY SIMPLE METHOD



The accompanying sketch shows how to do it. Slip gauge glasses into each end of an ordinary rubber hose and fill with enough water so that the level will show in each glass, as indicated.

When filling the hose with water, care must be exercised to be certain that all air is gotten out of the hose. Hold it in a U-position when filling. Do not attempt to fill it by immersing the hose in a tub of water. Also, one end of the hose must not be warmer than the other end. If the water in one end is warmer it will occupy greater volume and the level will not be true. In other words, get rid of all of the air and use water of the same temperature throughout.

The sketch also shows one of the simplest methods by which shafting can be aligned. Suspend several plumb bobs from the shaft as shown, all from the same side of the shaft. It is then possible to glance along from one end to the other and one can see whether or not the cords supporting the plumb bob are in perfect alignment. If they are not in alignment, the shafting is not straight and should be rectified. A cord stretched lengthwise near the vertical cords enables one to measure the exact amount of misalignment and assist in making the shaft straight.

RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

By PAUL F. HOWARD, M.S.*

Consulting Engr., Boston, Mass.

It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

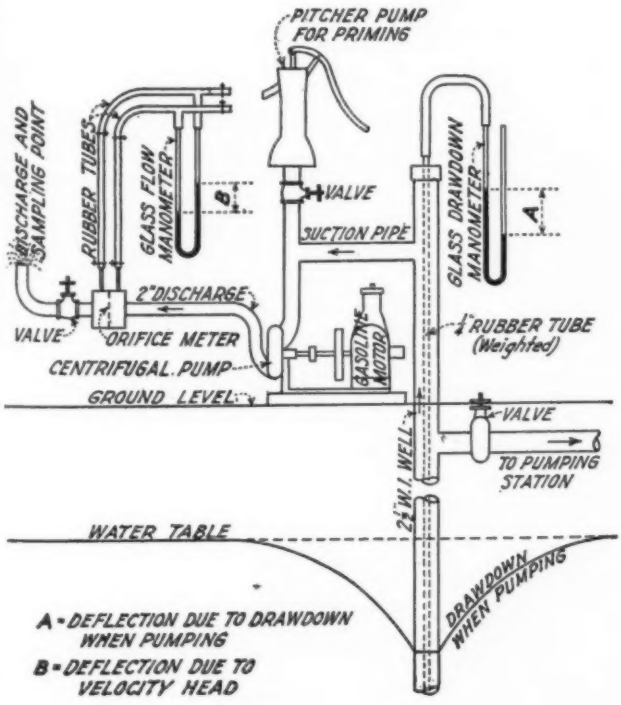
The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅛ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

THE DEMING COMPANY

ESTABLISHED 1880

SALEM, OHIO, U. S. A.

DEMING PUMPS

FOR WATER WORKS AND SEWERAGE

(Following listings appear in "Classified Index of Products" in this publication).

BOILER FEED PUMPS
CELLAR DRAINERS
CENTRIFUGAL PUMPS
CONDENSATION PUMPS
DEEP WELL PUMPS
DIAPHRAGM PUMPS
DRAINAGE PUMPS
PORTABLE PUMPS

Group of Factory Buildings of The Deming Company, Salem, Ohio.

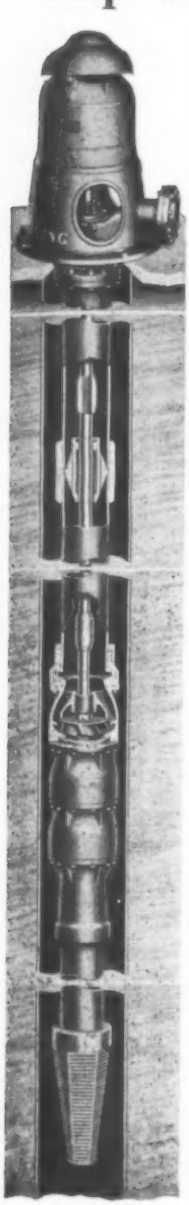
DEMING PUMPS

FOR WATER WORKS AND SEWERAGE

(Following listings appear in "Classified Index of Products" in this publication).

ROTARY PUMPS
SELF PRIMING PUMPS
SEWAGE PUMPS
SLUDGE PUMPS
SUCTION AND FORCE PUMPS
SUMP PUMPS
TURBINE PUMPS

Deep Well Turbine Pumps



These *water lubricated* deep well turbine pumps are designed to deliver capacities ranging from 15 to 3,000 gallons per hour and are widely used for municipal water supply, drainage, irrigation, swimming pools, etc.

The multi-stage vertical centrifugal pump construction allows the pumping unit to be placed at any depth from the surface, preferably submerged at all times.

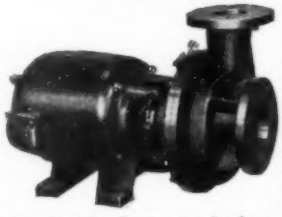
Vertical hollow-shaft motors are standard construction although other types of heads can be supplied such as belted drive heads, gear increaser heads, steam turbine heads, flexible coupling, or combination type heads.

Features of Deming Deep Well Turbine Pumps include semi-open, adjustable type impellers held in place with split tapered compression sleeves; Goodrich cutless rubber bearings of the fluted type are used in each bowl, or stage, and at a maximum interval of 10 feet in the column pipe. These bearings are thoroughly flooded and lubricated by the water being pumped. Stuffing box in the discharge head can be easily adjusted or repacked from ground level.

For complete information on Deming Deep Well Turbine Pumps, write for BULLETIN 4700-8.

Centrifugal Pumps

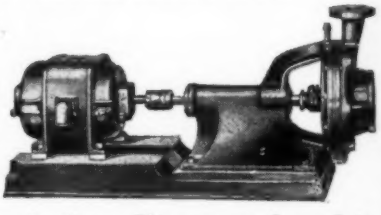
"MOTOR MOUNT" CENTRIFUGAL PUMPS



Compact, dependable units, Deming "MOTOR MOUNT" Pumps combine high efficiency and simplicity at moderate cost. There are 63 units in the line. Capacities range from 5 to 650 gallons per minute against heads from 10 to 85 feet. Features include semi-enclosed, three-vane impeller with non-overload characteristics; adjustable for capacity, head, clearance and wear. Motor is drip proof type with moisture resisting insulation. Deep groove, over-size ball bearings. Fan ventilation.

Complete data in BULLETIN 4301. Write for copy

SIDE SUCTION CENTRIFUGAL PUMPS



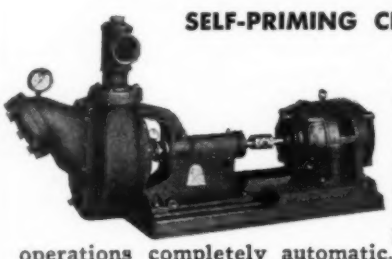
Standardized in design, Deming Side Suction Ball Bearing Centrifugal Pumps eliminate the need for expensive specially designed equipment for a wide scope of pumping requirements.

There are 21 pumps in the line. Sizes range from 1 to 10 inches. Capacities range from 10 to 3,600 gallons per minute against heads up to 260 feet.

Deming Side Suction Centrifugal Pumps can be furnished for belt drive, electric motor, or gasoline engine drive.

Complete data in BULLETIN 4200. Write for copy

SELF-PRIMING CENTRIFUGAL PUMPS



These electric motor-driven units are designed for sump pump service with float switch control. Also used for cleansing swimming pools, core sucking service in ice plants, etc. Priming operations completely automatic. Semi-enclosed, non-clogging impeller.

Pumps can be furnished direct connected through flexible couplings; or to electric motors; or gasoline engines; or with pulley for belt drive.

Capacities range from 600 to 18,000 gallons per hour.

Complete data in BULLETIN 3000. Write for copy

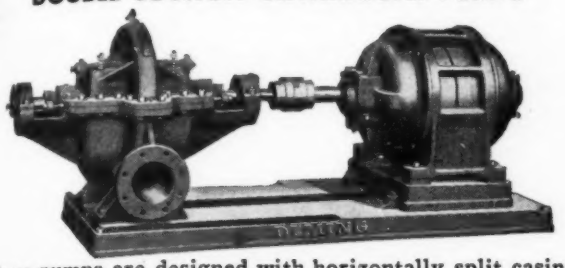
THE DEMING COMPANY

ESTABLISHED 1880

SALEM, OHIO, U. S. A.

Centrifugal Pumps

DOUBLE SUCTION CENTRIFUGAL PUMPS



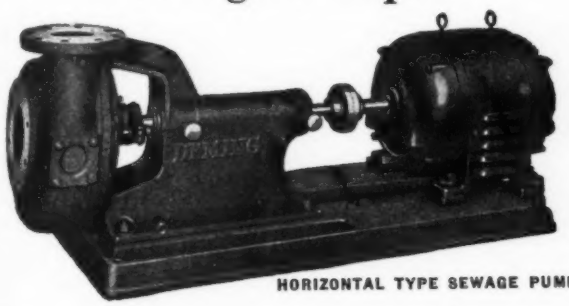
These pumps are designed with horizontally split casing. All features conform to latest engineering practice to obtain maximum efficiency for this type of unit. Recommended for working pressures up to 200 pounds.

Heavy ball bearings at each end of shaft take all lateral and end thrust. Rotating elements are in perfect static and dynamic balance, assuring a vibrationless pump at all speeds.

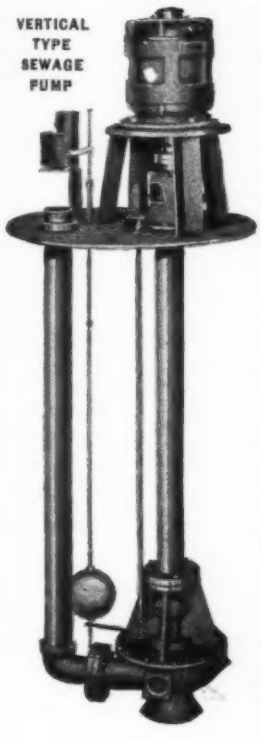
The line includes a wide range of sizes from 1½ to 10 inches with capacities up to 5,000 gallons per minute against heads up to 350 feet.

Complete data in BULLETIN 5003. Write for copy

Sewage Pumps



HORIZONTAL TYPE SEWAGE PUMP



VERTICAL TYPE SEWAGE PUMP

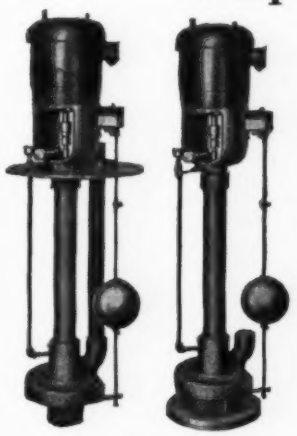
Deming non-clogging horizontal and vertical type sewage pumps are designed to handle safely and efficiently raw, unscreened sewage, storm water disposal, drainage, or other pumping requirements where liquids carrying along refuse, dirt, silt, rags, sticks, and stones must be handled with minimum danger from clogging, breakage, or undue wear.

These pumps are used in Sewage Disposal Plants, Paper Mills, Quarries, etc., and are suitable for many applications where standard Centrifugal Pumps are not designed for the indicated requirements.

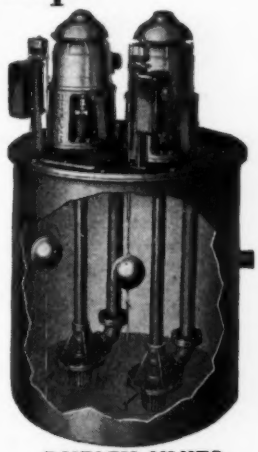
Deming Sewage Pumps are built in horizontal and vertical types for capacities from 60 to 1,200 gallons per minute and for heads not to exceed 80 feet.

As these pumps usually require individual engineering, a complete statement of conditions should accompany each inquiry.

Sump Pumps



SUMP PUMPS



DUPLEX UNITS

Deming Sump Pumps are designed in various types in a wide range of capacities from 10 to 3,200 gallons per minute with heads up to 120 feet and speeds from 860 to 1,750 r.p.m. for motor drive.

Construction of Deming Sump Pumps offers many important features including: (1) Impeller adjustable for capacity, head and wear; (2) Impeller fitted to shaft with taper, key and nut; (3) Full weight column pipe with precision thread; (4) Double length bottom shaft bearing with large grease chamber.

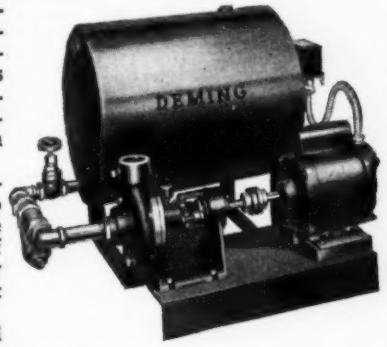
Deming Sump Pumps are furnished either in SINGLE or DUPLEX units of either wet or dry pit type. Can be installed in pits of every description wherever water collects and has to be emptied into sewer lines at a higher level or delivered above ground.

Duplex units meet requirements where extra precautions must be taken to insure uninterrupted service.

The complete line of Deming Sump Pumps is illustrated and described in detail in BULLETIN 4603. Write for copy

Condensation Return Units

DEMING 4010-RC UNIT



Deming pump and receiver units are designed to return, automatically, to boilers the hot water of condensation from radiators, coils, and steam operated machinery. Condensate is automatically returned to the boiler by the pump, operation of which is controlled by an enclosed float switch. Units are equipped with horizontal reciprocating pumps or side suction centrifugal pumps, depending upon capacity, pressure, and most efficient operation.

Receiver tanks are of extra heavy welded boiler plate. Tanks furnished with water gauge glass and with petcock and check valve in top, as illustrated.

Motors are furnished single phase, 2 or 3 phase, or direct current as specified. All units are equipped with motor protective device and are completely assembled and wired.

CAPACITIES: 79 units in the line cover a range of pump capacities from 2.25 gallons per minute to 60 gallons per minute. Write for complete information, which includes performance table of capacities, pressures, and other data.

FIRE HYDRANT FLOW GAGE

A Pressure Gage With a GPM. Discharge Scale

By A. A. HIRSCH*
State Dept. of Education, Baton Rouge, La.

MEASUREMENT of flow from a fire hydrant is a useful procedure in many ways. Probably the most important application is in evaluation of available fire flows at various sections of a distribution system. Often employed when chlorinating new or repaired mains, a measured withdrawal from a fire plug synchronizes water flow and chlorine feed for uniform mixing. Hydrant flow measurement is also an essential step in the incremental method for determining the C value for a pipe line. When flushing mains through fire hydrants to clear out the distribution system a knowledge of the flow enables an operator to estimate the time required for complete displacement and also to record the amount of water allowed to waste.

Of the several methods in vogue for hydrant flow measurement, namely the special pitot tube-gage combination, the stream trajectory, the short tube with terminal orifice, and the velocity head reading by means of a pressure gage on a closed cap, the last named is the one most generally employed by reason of its simplicity in principal and equipment.

The Procedure

In determining flow from a fire hydrant by the pressure gage method all that is needed is to connect an accurate gage to the closed nozzle, and discharge the hydrant through the other nozzle. The flowing nozzle may be considered as a "short-tube"

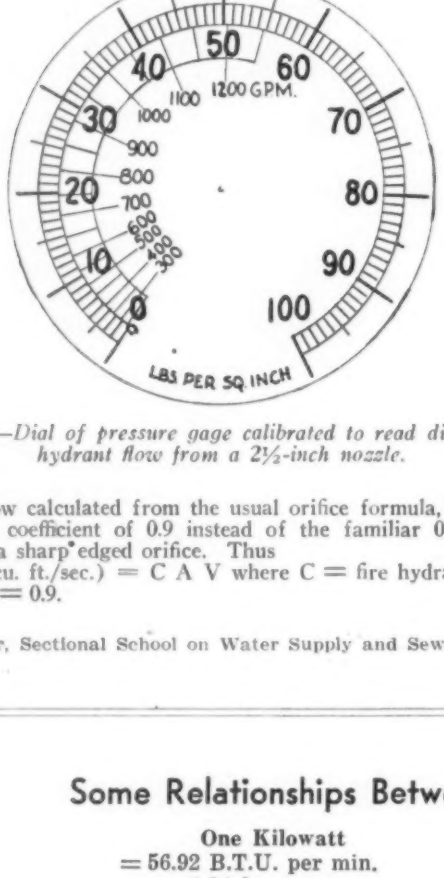


Figure 1.—Dial of pressure gage calibrated to read directly fire hydrant flow from a 2½-inch nozzle.

and its flow calculated from the usual orifice formula, but using an orifice coefficient of 0.9 instead of the familiar 0.61 which holds for a sharp-edged orifice. Thus

Flow (cu. ft./sec.) = C A V where C = fire hydrant orifice coefficient = 0.9.

$$A = \text{area of nozzle (sq. ft.)} = 0.785 \times \frac{\text{Diameter}^2_{\text{(inches)}}}{144} = 0.00545\ \text{Diameter}^2_{\text{(inches)}}$$

$$V = \sqrt{2\ g\ h_{\text{ft. water}}} = \sqrt{2 \times 32.16 \times 2.31 \times \text{Pressure}_{\text{psi.}}}$$ the pressure reading being taken off the closed nozzle

$$= 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

Substituting in the first equation:

$$\text{Flow (gpm.)} = 7.48 \times 60 \times 0.9 \times 0.00545\ \text{Diameter}^2 \times 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

$$= 27\ \text{Diameter}^2_{\text{(inches)}}\sqrt{\text{Pressure}_{\text{psi.}}}$$

This is the familiar form commonly used to calculate the discharge from a fire hydrant.

Ordinarily the 2½-inch nozzle is used, as the 4- or 4½-inch nozzles do not conform with accuracy to a simple formula. Substituting the value of 2½ inches for the diameter in the above formula there results

$$\text{Flow (gpm. through 2½ in. nozzle)} = 27 \times 2.5^2 \times \sqrt{\text{Pressure}_{\text{psi.}}} = 168.7\sqrt{\text{Pressure}_{\text{psi.}}}$$

from which the discharge through a 2½-inch hydrant nozzle may be conveniently calculated.

The Self-Calculating Gage

Inasmuch as a given velocity head on the pressure gage corresponds to a fixed discharge the gage may be calibrated to read this flow directly and thereby obviate the need for calculation. A dial so calibrated is illustrated in Fig. 1. By marking off a dial in this manner the gage may be used in hydrant flow studies to facilitate discharge adjustments and to enable flow evaluation on the spot without calculations or conversions. Fig. 1 may also be used as an approximate solution to the hydrant formula for a 2½-inch nozzle rather than perform the numerical substitutions.

The accuracy of the pressure gage should be checked on a cold test apparatus, especially in the low pressure range below 500 gpm. where slight inaccuracy causes relatively large errors in the indicated discharge. If the test gage is off the needle position may be reset, the linkage between hollow spring and sector adjusted as required, or a calibration curve drawn to show the true pressure corresponding to any gage reading. From Fig. 1 it will be noted that below a flow of about 250 gpm. the type of pressure gage as illustrated is inapplicable since it fails to deflect.

For flows below this lower limit the discharge is measured by such methods as (1) large water meter, (2) the time required to fill a barrel through a short section of hose, (3) a more sensitive gage or manometer, (4) a special hydrant nozzle with terminal sharp-edged orifice, or (5) measuring the offset distance from the barrel to a point where the stream has dropped one foot, and referring to a calibration curve.

*Director, Sectional School on Water Supply and Sewerage.

Some Relationships Between Current Flow and Heat Production

One Kilowatt
= 56.92 B.T.U. per min.
= 1.34 horse-power.

One B.T.U. per Min.
= 0.01757 KW.
= 0.02356 H.P.

One Horse Power
= 42.44 B.T.U. per min.
= 0.7457 KW.

One Horse Power/Hour
= 2,547 B.T.U.
= 0.7457 KW.H.

One Kilowatt/Hour
= 3.415 B.T.U.
= 80.46 H.P.

DEVELOPMENT OF ROCK WELLS

By J. ARTHUR CARR*
Supt., Dept. of Water Supply, Ridgewood, N. J.

THE Department of Water Supply of the Village of Ridgewood, N. J., has applied in rock wells some of the mechanics of development which had been heretofore applied only to sand and gravel wells. In every case where the method of development described herein has been used, the yield of the well has been materially increased.

It has generally been accepted that when drilling was completed in a rock hole nothing further could be done to the well to increase the yield. The few experiments, however, completed up to that time had indicated that the yield of many wells in red sandstone formation, as occurs in northern New Jersey, could be increased by agitation.

Since 1941 seven new wells have been constructed by the village of Ridgewood. All were developed by agitation after drilling had been completed and in every case the yield was increased in amounts varying from 32 to 180 per cent.

The improvement secured by development was not confined to new wells. In two instances the pumps were removed from wells drilled in 1932 and those wells were given several days of agitation with a resulting increase in yield of 150 per cent.

Developing Procedure

The method used in developing a 12-inch well is briefly as follows: The well wall is first thoroughly scrubbed for its entire depth to remove all loose particles of rock and any clay that may have adhered to the well wall. Scrubbing is accomplished with a specially constructed steel brush—see Fig. 1. The brush is one-half inch larger in diameter than the diameter of the well and is made up of ¼-inch steel bristles.

A 5-foot plugged nipple slightly less than 12 inches in diameter is attached to a steel cage 20 feet long. The nipple and cage are then attached to a 12-inch hook wall packer and the whole assembly lowered to the bottom of the well on a string of 8-inch pipe. The packer is then expanded against the well wall—see Fig. 2.

For agitation, or surging, a long heavy steel valve type plunger is operated inside of the 8-inch pipe. The diameter of the plunger is only slightly less than the diameter of the 8-inch pipe—see Fig. 3.

Because of the packer at the top of the cage and the nipple at the bottom of the cage serving as plugs, practically all of the action or surge force created by the plunger is concentrated on the portion of the well wall exposed by the 20 feet of cage. All heavy sand and pieces of rock dislodged are caught in the plugged nipple at the bottom of the cage which acts as a trap—Fig. 3.

The well is bailed frequently and, when no more material is being brought into the trap, the packer is tripped, the assembly is raised twenty feet and the packer again expanded. The operation is repeated until the entire well wall has been subjected to agitation.

Experiences and Costs

In some instances as much as 4 cubic yards of sand, clay and particles of rock have been removed from the trap in the course of developing a 12-inch well, 350 feet deep.

Naturally the cost of a well per foot of depth is considerably increased when developed by the method described, as in some cases the time expended in development has been equal to, or greater than, the time expended in the drilling operation. The cost of water per gallon produced, however, has in almost every case been less after development.

The accompanying tabulation gives the details of costs for eleven wells, both before and after development by the method described.

It may be noted that, while development increased by 60 per cent the cost per lineal foot of well (average for eleven wells), the cost per gallon of water produced was decreased by 15 per cent when average figures are considered.

While the saving in cost per gallon produced is apparent, there is a still further and greater saving effected by a marked reduction in the number of pumps, pump houses, piping, wiring, controls, etc., necessary to deliver the amount of water which may be required. As shown in the tabulation, at a comparatively slight increase in the cost of equipment, the eleven wells can deliver almost twice as much water as would have been delivered had they not been developed.

There is a still further saving to the Ridgewood Water Department reflected in the tabulation. If the wells, indicated as the Ames group, had not been developed the amount of additional water secured from that field would not have been sufficient for present needs. It would then have been necessary to seek other sources, with a consequent outlay for land, additional supply lines, etc.

Fig. 1—The Wall Brush

Drilling Care Pays

Extreme care is necessary in the drilling operation if a well is to be developed by the method described. The hole must be drilled to full gage as any slight constriction will prevent lowering the cage and packer to the desired depth.

The well must also be perfectly straight for its entire depth. The assembly of trap, cage and packer is about 30 feet over all and it would be impossible to lower it on a string of 8-inch

TABLE 1 Cost Data

Year	Location	Size	Depth	TOTAL WELL COST Before Devel.	TOTAL WELL COST After Devel.	GALLONS YIELD Before Devel.	GALLONS YIELD After Devel.	COSTS PER LIN. FT. Before Devel.	COSTS PER LIN. FT. After Devel.	COSTS PER GALLON Before Devel.	COSTS PER GALLON After Devel.
1940	Farview Street	12&10	402	2,240.50	2,835.50	290	370	5.57	7.05	7.73	7.66
1941	Wortendyke No. 2*	12,10,8	1,137	3,150.52	5,060.52	80	229	2.77	4.45	39.38	22.10
1941	Ames No. 2	12	480	1,756.82	2,996.82	70	175	3.66	6.24	25.10	17.12
1941	Ames No. 6	12	455	2,169.07	3,509.07	150	250	4.77	7.71	14.46	14.04
1941	Ames No. 9	12	350	1,638.12	2,603.13	80	170	4.60	7.43	20.48	15.31
1933	Cedar Hill No. 2†	12	399	2,682.26	3,997.26	100	250	6.72	10.02	26.82	15.99
1932	Cedar Hill No. 3†	12	500	2,801.90	4,196.00	100	250	5.60	8.39	28.01	16.78
1942	Ames No. 3	12	352	1,476.74	2,831.74	180	360	4.20	8.04	8.20	7.87
1942	Ames No. 5	12	350	1,883.28	3,332.77	185	245	5.38	9.52	10.18	13.60
1943	Ames No. 1	12	350	1,934.64	3,177.89	65	180	5.53	9.08	29.76	17.65
1943	Ames No. 7	12	352	1,996.99	3,429.75	150	260	5.67	9.74	13.31	13.19
	Totals and Averages	..	5,127	23,730.85	37,970.45	1,450	2,739	4.62‡	7.40‡	16.36‡	13.86‡

Remarks: *From 215'-1,137'only. Original 215' drilled 1926.
†Drilled 1932 and 1933; Developed—1942.
‡Averages.

*The author is co-chairman of the A.W.W.A. Committee on Deep Wells and Deep Well Pumping.

Fig. 2—Plunger (left), Upper Section of Cage and Hook Wall Packer Above.

pipe to a depth of some 400 or 500 feet if there were any kinks or dog legs in the well hole.

In the developing operations an experienced well rig operator is also essential. The hook wall packer requires careful handling and operation and in a 500-foot well it must be set, tripped and reset twenty-five or more times in the complete development process.

Much interesting and often valuable information is secured incidental to development. In most cases two water levels are maintained at all times, one inside the 8-inch pipe from below the packer and one outside the 8-inch pipe from above the packer. Frequently these levels change at each different setting of the packer. By a study of the record of water levels in conjunction with a comparison of drilling samples and samples of material brought in by agitation it is possible to determine at what elevation or elevations water is entering the well.

The work done in Ridgewood was contracted on the day basis, the contractor furnishing all necessary labor, tools and equipment at a flat sum per day. Fortunately the contractor's interest in the new methods being used was as keen as that of the village authorities. Much of the equipment such as the cage, steel plunger and wall brush were produced by the contractor in his own shop.

Much can be gained by the described development of wells in the red sandstone of northern New Jersey, and application of similar methods should be successful in wells drilled in other types of consolidated formation.

Fig. 3—Bottom Section of Cage and Sealing Nipple and Trap Below.

HOW TO COMPARE PUMP EFFICIENCIES*

IF the efficiency of your present pump is 74% and you are planning to install a new pump whose efficiency will be 85%, the improvement will not be merely 11%. There will be an improvement of 13% in efficiency.

It is not uncommon for users and prospective users to subtract the efficiency of the old pump from that of the new one and call the difference the "improvement" in efficiency, but that is not correct. The correct method is to subtract the two efficiencies and then divide the difference by the efficiency of the new pump.

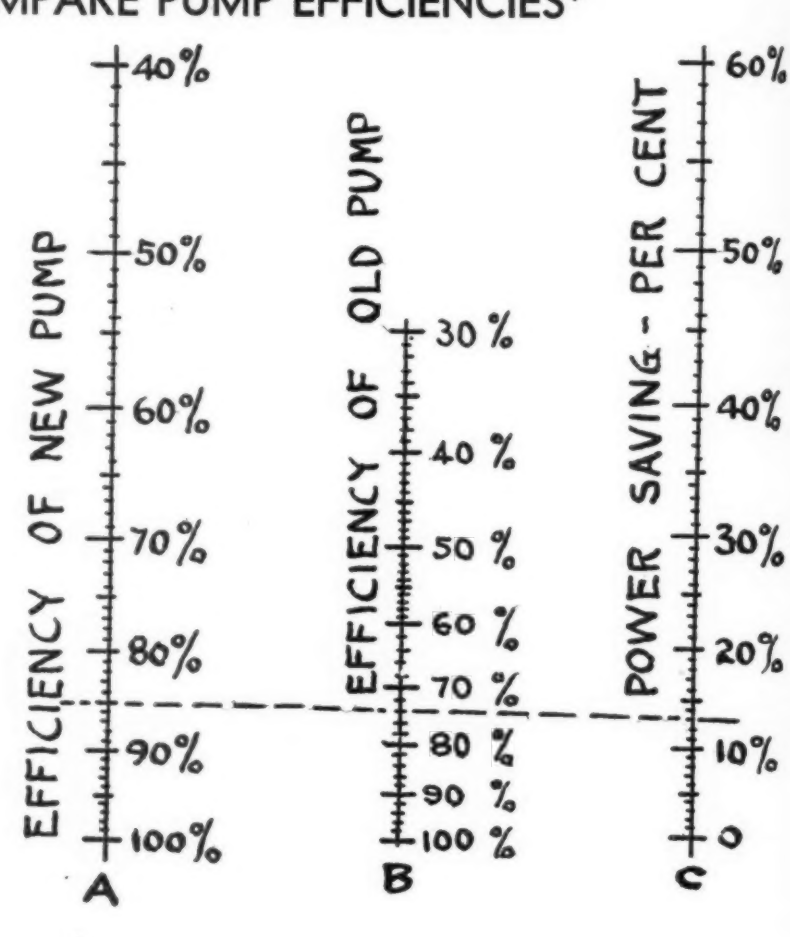
Thus, for example:

$$0.85 - 0.74 = 0.11$$
$$0.11 \div 0.85 = 0.13$$

which verifies the figures given above.

Let us suppose that you have a pump whose efficiency is only 40% and you are contemplating the installation of one whose efficiency will be 80%. The difference between the two efficiencies is 40%, but that is not the correct improvement. The true improvement is $40\% \div 80\% = 50\%$.

Herewith is a chart that gives the true improvement or "power saving" without any longhand figuring whatever. Simply run a straight line through the efficiency of the new pump, column A, and the efficiency of the old pump, column B, and the power saving or improvement in efficiency is instantly given in column C. Thus the dotted line drawn across this chart shows that where the efficiency of the new pump is 85% and that of the old pump is 74%, the true improvement which can be expected in power saving is 13%.



*Contributed by W. F. Schaphorst, M. E.

WATER HAMMER

Its Study and Correction

By HENRY RYON

Late Senior Sanitary Engineer
New York State Department of Public Works, Albany, N. Y.

IN ORDER to provide water for Clinton Prison at Dannemora, N. Y., it was found necessary to use Chazy Lake as a source of supply and to lift the water over Dannemora mountain to the prison reservoir. This required the installation of a pumping station and a force main about 4½ miles long with a rise of 530 feet. The pumping station and pipe line were put in operation late in 1932, and almost immediately trouble was experienced due to the failure of the lead joints in the pressure line. The cause of these failures was apparently the high pressures developed when the pumps were stopped, and studies were made to determine the best method of reducing these high pressures.

Installation

The pumping equipment consists of two electrically driven four-stage centrifugal pumps each having a capacity of 390 gallons per minute against a head of 619 feet. The pumps are set approximately at normal lake level. The suction line is of 10-inch cast iron pipe and is about 400 feet long. The discharge main is of 8-inch cast iron bell and spigot pipe, Class G to Class B, and is 23,720 feet long. The static head at the pumps is 530 feet, the equivalent of approximately 230 pounds per square inch. There is a standard swing check valve on the suction line and a similar check on the discharge line of each pump. A 6-inch spring loaded relief valve and an air chamber 8 inches by 96 inches in size were provided on the main discharge line near the pumps.

Line Pressure

In order to study the pressures in the discharge line a recording pressure gauge with a fast moving chart was connected to the line just beyond the relief valve. A typical pressure curve plotted by this gauge with one pump in operation and the relief valve and air chamber shut off is shown in Fig. 1.

The static pressure is 230 pounds per square inch. When one pump is started the pressure gradually rises to 310 pounds per square inch, the rise for each of the four steps of the starter showing distinctly, and then drops to the running pressure of 275 pounds per square inch. When the pump is stopped the pressure drops very quickly from 275 pounds per square inch to 90 pounds per square inch and then rises to 370 pounds per square inch. These subnormal and supernormal pressures continue at regular intervals, the variations above and below the static pressure becoming less and less as line friction gradually damps them out. The time of one complete cycle is 23.1 seconds, and since the water-hammer wave must travel four times the length of the pipe in one cycle, its velocity is at the high speed of 4,110 feet per second. By comparison, the maximum velocity of flow in the pipe, with one pump in operation, is only 2.49 feet per second.

It is, of course, the first super-normal pressure wave that causes most of the pressure wave cannot, however, be neglected for it very definitely limits the damage to the pipe line. The subnormal amount of air that can be retained in the air chamber.

Water Hammer Waves

In order to explain the method evolved to control the water-hammer pressures, it is necessary to consider first the nature of a water-hammer wave. The magnitude and velocity of the wave depend upon the elasticity of the material composing the pipe wall, the velocity of the water in the pipe and the time in which that velocity or part of that velocity is extinguished. The yare independent of pressure in the pipe and flow velocity, except that part of the velocity that is extinguished. The water-hammer pressure or excess pressure is the variation above or below normal caused by the water-hammer wave. In this case (and in other cases where conditions are similar) the momentum ceases to deliver water almost instantly. The suction line being short, no high pressure of any duration is developed in it that of the rotating parts of the pump and motor is so small in comparison with the load that when the switch is opened the pump might force water through the pump. As a result the stopping of the pump has for all practical purposes the same effect as almost instantaneously closing a valve.

An Analysis

This effect can be examined best by considering the pipe line to be divided into a large number of very small sections of equal length.

When a valve at the inlet end of a pipe in which water is flowing is instantaneously closed, the velocity of the water in the section adjacent to the valve (in this case the pump), is immediately extinguished. This causes the water in this first section to expand, the pressure to fall and the pipe to contract. In other words, the kinetic energy of the moving water has been converted into potential energy. The water in the first section being at rest or static, the velocity of the water in the second section must necessarily cease. The water in the second section then expands, the pressure falls and the pipe contracts in the same manner as in the first section. This reduction in pressure in the second section in no way affects the pressure in the first section for the pressure in that section, excepting gravity and friction, is dependent entirely upon the destruction of the kinetic energy of the water in that section. And, the kinetic energy of the water

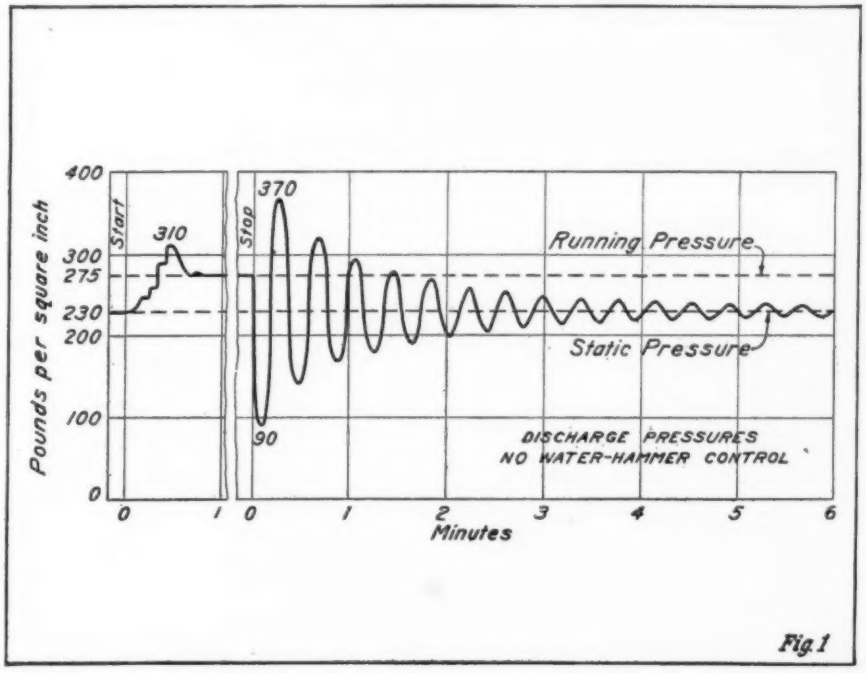


Fig. 1.—Typical Pressure Wave Graph
(One Pump Thrown Out; Relief Valve and Air Chamber Shut Off At the Time)

in the second section is exactly the same as that of the water in the first section and its destruction therefore produces exactly the same reduction of pressure. This process continues through the third, fourth and other sections of the pipe until all the water in the line has expanded, the entire pipe line contracted and the pressure throughout fallen by the same amount. The wave has traveled the length of the pipe once and the water is at rest.

This condition, however, is not stable. The water in the lower end of the pipe cannot move, but the water inthe upper end is freeto contract. This it does immediately. The water in the upper section contracts, the pressure rises and the pipe expands. As a result of this contraction of the water and the expansion of the pipe in the upper section, water flows into the pipe. Conditions in the upper section having thus changed, the second or adjacent section is free to move. The water in the second section then contracts, the pressure rises and the pipe expands. This draws more water into the pipe. In a like manner similar changes occur in the third, fourth and other sections until all the water in the line has again contracted, the entire pipe line expanded and the pressure throughout risen to the point (excepting friction at which it was before the valve was closed or the pump stopped. The wave has traveled the length of the pipe twice. The water is in motion and is flowing toward the pump with the same velocity, excepting for friction losses, at which it was flowing away from the pump before the pump was stopped.

This flow cannot continue, for while the wave has been traveling twice the length of the pipe, ample time has elapsed (11.5 seconds in this case) for the check valve at the pump to close tightly. The flow is therefore directed toward a closed valve and the velocity in the first section adjacent tothe check valve is instantly extinguished. The water in this section is compressed, the pressure rises and the pipe expands. The water in the first section being at rest, the water in the second section must necessarily come to rest with the same changes in condition as occurred in the first section. In a like manner, the water in the third, fourth and other sections come to rest successively until all the water in the pipe line is at rest and compressed, the pressure above normal and the pipe expanded for its entire length. The wave has traveled three times the length of the pipe and the water is once more at rest.

Again, however, the conditions are unstable. The water in the lower end of the pipe cannot move but that in the upper end is free to expand. This it does immediately. The water in the first section expands, the pressure falls and the pipe contracts causing water to flow out of the upper end. Conditions having changed in the upper or first section, the second section is free to move. The water in the second section then expands, the pressure falls and the pipe contracts causing a further flow of water out of the upper end of the pipe. Similar changes occur in the third, fourth and other sections of the pipe until all the water in the pipe has expanded, the entire pipe line contracted and the pressure (except for friction losses) fallen to the normal running pressure. The wave has traveled the length of the pipe four times. The water is moving away from the pump with the same velocity, excepting friction losses, that it was before the pump was stopped. In other words, one cycle has been completed, and conditions are the same as when the pump was running.

The cycle repeats itself until the friction gradually damps out the wave.

A diagram of the effect of this wave near the pump is shown in Fig. 2. The complete cycle is from A to G. The slope of the line from B to C is due to the fall in friction pressure as the wave passes up the pipe and the water gradually comes to rest.

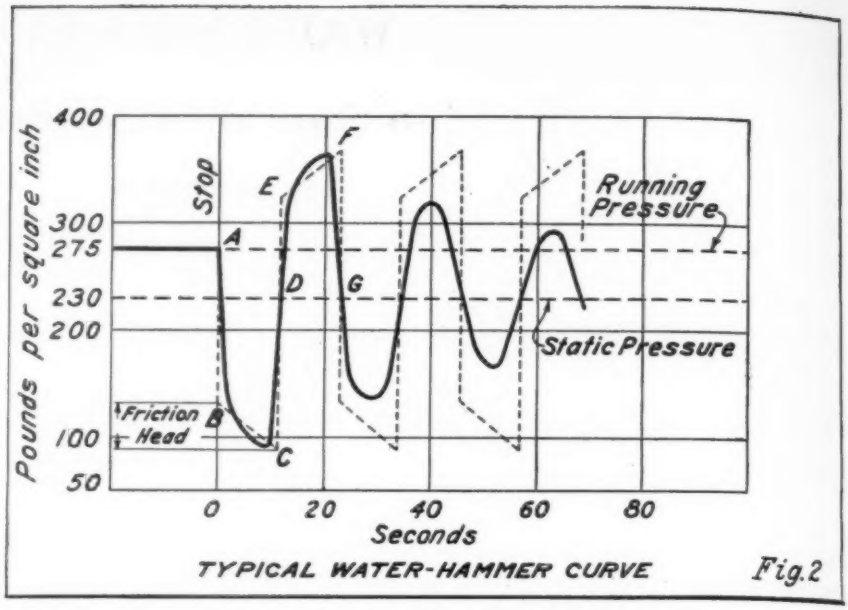


Fig. 2.—Graph of Wave Near the Pump (Explanation of Significance in Text)

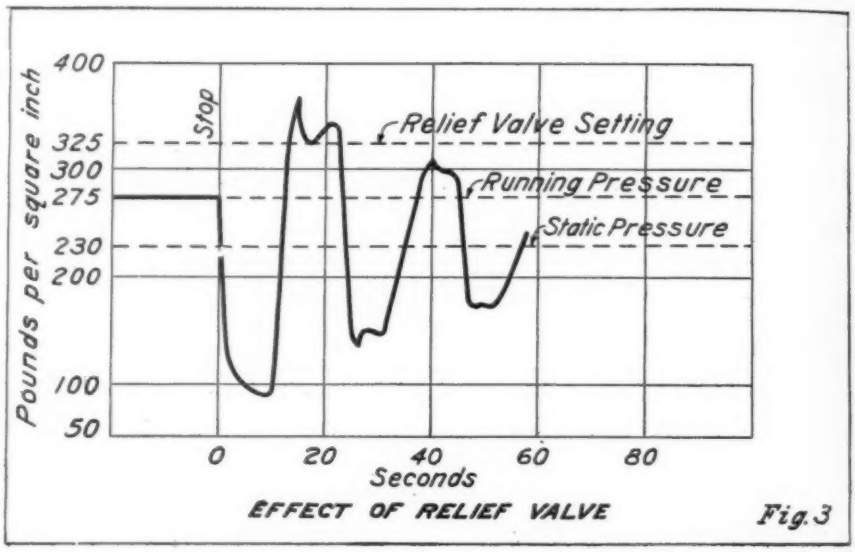


Fig. 3.—Graph Revealing Failure of Spring-Loaded Relief Valve to Relieve

The slope from E to F is due to the rise in friction pressure as the velocity away from the pump is gradually regained.

A comparison of the velocities and pressure as observed and those computed by Joukovsky's formula (Jour. Am. Water Works Assoc., 1904, p. 341); (W. W. and S., April, 1938, p. 338) is interesting.

Joukovsky's formula for waterhammer, produced by instantaneous valve closure, is:

$$H = \frac{aV}{g}$$

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{K} + \frac{D}{Ee}\right)}}$$

H = Head due to water-hammer, ft.
a = Velocity of water-hammer water, f.p.s.
V = Velocity of water in pipe, f.p.s.
g = Acceleration of gravity.
w = Weight of one cubic foot of water.
K = Bulk modulus of elasticity of water, pounds per sq. in.
E = Modulus of elasticity of pipe material, pounds per sq. in.
D = Diameter of pipe, inches.
e = Thickness of pipe wall, inches.

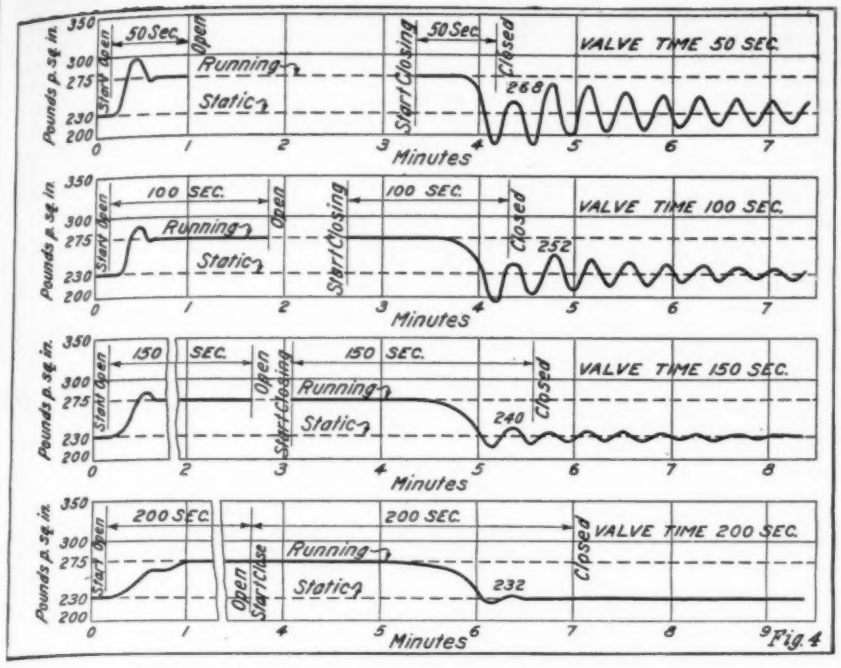


Fig. 4.—Graph Showing Results With a Cone Valve

The value of studying the effects of various closure times for surge suppression is effectively revealed in the four recorded graphs. A splendid testimonial as to the efficacy of properly controlled cone valves

The results are as follows:

Computed water-hammer head (negative)	326 ft.
Observed water-hammer head (negative)	322 ft.
Computed velocity of water-hammer wave	4220 f.p.s.
Observed velocity of water-hammer wave	4110 f.p.s.

If the pipe line had been shorter or the time of stopping longer so that the water-hammer wave set up by the first reduction in the discharge of the pump could have traveled to the end of the pipe and returned to the pump before the flow through the pump had stopped the returning supernormal wave would have interfered with the subnormal wave and the magnitude of the wave would have been reduced. So long as the returning wave does not reach the pump until its discharge is entirely stopped

$$t < \frac{aL}{2}$$

the result, for all practical purposes, is the same as that produced by an instantaneously closed valve. If it does return before the pump discharge has ceased, the interference of the waves must be considered. Except for this interference, the *water-hammer pressure is independent of the length of the pipe.* In the suction line which is only 400 feet long, the first wave returns in 0.2 of a second and interferes with the following waves, preventing, as stated before, the development of a pressure in the suction that might force water through the pump.

Relief Valves

When the Chazy Lake pumping station was built, a 4-inch spring loaded relief valve was installed on the 8-inch discharge line for the purpose of preventing any undue rise in pressure. This relief valve failed to produce the desired result. The effect of the relief valve on the water-hammer pressures is shown in Fig. 3. The inertia of the moving parts in the valve apparently prevents it from opening rapidly enough to relieve the pressure and the head rises almost to the same value that it does without the valve in operation. When it finally does release the water the pressure falls to that for which the valve is set. The valve then closes and stops the flow of water through it. The stopping of this flow sets up another water-hammer wave and the pressure again rises.

In order to satisfactorily prevent high pressures by means of a relief valve, the valve must open *before* the first returning wave reaches the pump. That is, before the pressure reaches the point D in Fig. 2. At this time the water in the line is flowing toward the pump and the pressure is the normal static pressure. If the valve is open at this time the water will flow out of the valve with no material rise in pressure. The valve must close slowly or the stopping of the flow through the valve will set up another water-hammer wave with consequent high pressures. It is generally necessary to provide an auxiliary source of power if this method of preventing high pressures is used because the pressure in the line is subnormal at the time the valve must start to open and usually insufficient to operate any type of valve.

This arrangement is used effectively at the Dalecarlia Pumping Station, Washington, D. C. (Water Works and Sewerage, April, 1938, Page 353). In this case the relief valve is of the hydraulically operated rotary plug type and the power for opening it is obtained from an independent water main near the station.

Air Chambers

The 8-inch by 96-inch air chamber provided on the discharge line from the pumps was found on test to be of absolutely no value in reducing the water-hammer pressures, and computations by the graphic method of Prof. Angus indicated that no reduction could be expected. An air chamber on the discharge line of a pump acts by supplying water to the line in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line instead of a suddenly closed valve.

To prevent high pressures in a pipe line by closing a valve slowly instead of rapidly requires that the time of closing be considerable, and if an air chamber is to be effective it must supply water to the line for a considerable time. Not only must the air chamber be large enough to contain sufficient water to

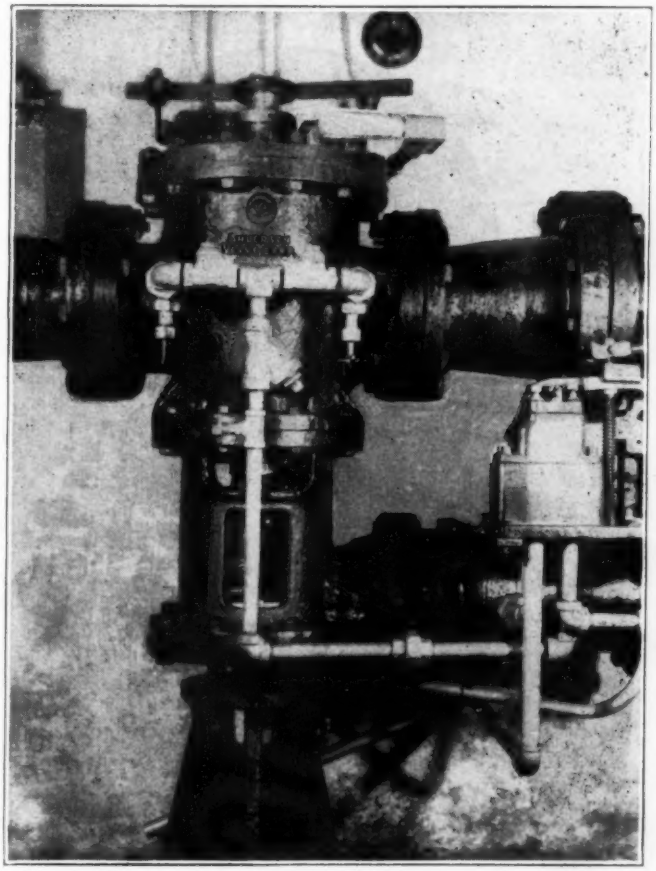


Fig. 5.—The Cone Valve
Which, with proper setting for closing time has solved the water-hammer problem

maintain this supply over the necessary period, but there must be sufficient air above the water to maintain the proper pressure on the water as the air expands. Air chambers, if they are to produce any measurable effect, must be far larger than those usually provided and often so large as to be impractical.

Cone Valve in Discharge Solves the Problem

The method now used at the Chazy Lake pumping station to eliminate the high water-hammer pressures is to reduce slowly the velocity in the discharge line before the pump being used is stopped—this instead of allowing velocity to be suddenly extinguished by the stopping of the pump. This is accomplished by a 6-inch hydraulically operated cone valve located in the main 8-inch discharge line near the pumps (see picture). The cone valve is in closed position when the pump is started. Since a centrifugal pump requires the smallest amount of power when operating against a closed valve, the motor thus starts under minimum load. As soon as the pump reaches its normal speed the cone valve slowly opens, the time of opening being controlled by the setting of a needle valve on the water feed-line to the hydraulic cylinder operating the cone valve. When it is desired to stop the pump the cone valve is first closed slowly, gradually reducing the velocity in the discharge main. After the valve is entirely closed the pump is stopped in the ordinary manner. Electrical interlocks are provided so that the attendant cannot change the order of the operations.

Results

The results of this method of operation, for different timings of the valve, are shown in Fig. 4. This valve rises from its seat before turning and reseats itself after completing its rotary motion. The time given for opening and closing is the time taken for the valve to rotate through 90 degrees, and does not include the time taken for unseating and seating. There is some leakage past the plug when it is raised from its seat, and the stoppage of this leakage by the seating of the valve in some cases causes a slight secondary wave, as is noticeable in some of the curves. The destruction of the velocity in the pipe line is, of course, not proportional to the amount of rotation of the valve as is evident from the fact that the first 2/3 of the revolution produces no measurable effect on the pressure. The effective closing time is therefore only a fraction of the actual closing time. Setting the valve to close in 50 seconds keeps the water-hammer pressure below the running pressure. Further, increasing the time of closing reduces the water-hammer pressure until with a closing time of 200 seconds the excess pressure caused by water-hammer is scarcely noticeable.

At this pumping station only one pump should be operated at a time if economical results are to be obtained. Two pumps can, however, be operated at once with a consequent decrease in the delivery per pump and a decrease in efficiency. The water-hammer pressure produced by closing the cone valve with two pumps in operation is practically the same as that produced by closing the valve with one pump in operation, the time of closing being the same. The reason for this is that while the actual closing time is the same, the effective closing time, as indicated by the curves, is about twice as long with two pumps in operation.

This method of reducing water-hammer pressures does not protect the discharge line from water-hammer pressures due to power failure. Such protection can be afforded only by a properly timed relief valve operated by a separate source of power or by the use of an air chamber, both of which methods have been previously mentioned. In the case of the Chazy Lake pumping station, neither of these methods seemed practical because of the difficulty of securing a separate source of hydraulic or other power; and, the very large size of the air chamber required to produce even a small reduction in the excess pressure. At this station the water-hammer pressures do not rupture the pipe but do strain the lead joints, and the high pressures can be repeated several times before leaks occur. For these reasons, it was decided to protect the pipe line against the high pressures produced by the daily starting and stopping of the pumps, and to risk occasional high pressures due to power failures which may occur at very infrequent intervals.

Hazleton Type "M"

CHECK VALVE

with Built-in Mercoid Motor Shut-off Switch for Automatic Pump Protection

PROTECTS PUMP FROM DAMAGE DUE TO LOSS OF WATER

PREVENTS OPERATION OF PUMP UNTIL PROPERLY PRIMED

The purpose of the flow switch is to insure pump against damage in the event that the pump loses its water during operation. The mercoid switch is actuated by the valve flap. Normally the switch is open when the flap is down. When the pump delivers water, the flow through the valve raises the flap and closes the switch. The mercoid switch is connected into the no-voltage coil of the motor starter.

When using a hand starter, the pump can be started up by hand, whether delivering water or not, but when the hand is removed from the starting lever, the pump will immediately stop unless the pump is delivering water and the mercoid switch of the check valve closed. With an automatic starter the "start" push button must be held in until the pump delivers water and closes the check valve switch.

Let us quote on your requirements

BARRETT, HAENTJENS & CO. - - Hazleton, Penna.

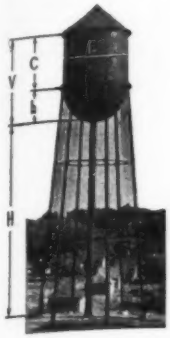
PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE STREET, DES MOINES, IOWA
ROOM 918—270 BROADWAY, NEW YORK . . . 1222 FIRST NATIONAL BANK BLDG., CHICAGO, ILL.
1223 PRAETORIAN BLDG., DALLAS, TEX. . . . 625 RIALTO BLDG., SAN FRANCISCO, CALIF.

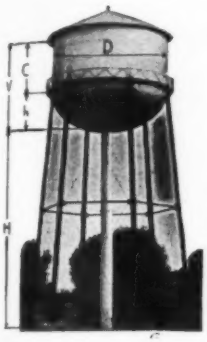
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



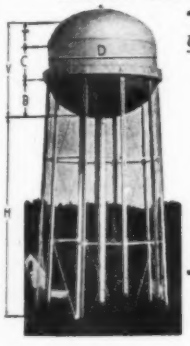
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



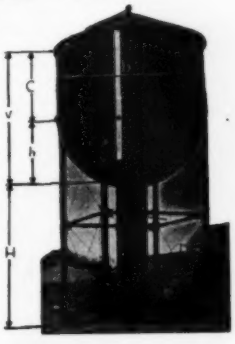
Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	...	.....	.....
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 8
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 8
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks



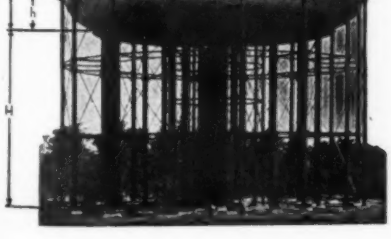
Capacity in U.S. Gallons	D	B	C	T	V	H
50,000	22'-0"	5'-10"	9'-4"	4'-4"	19'-6"	
75,000	26'-0"	7'-0"	9'-0"	5'-0"	21'-0"	
100,000	28'-0"	7'-0"	11'-1"	5'-7"	23'-8"	
150,000	34'-0"	10'-0"	8'-8"	6'-10"	25'-6"	
200,000	36'-0"	9'-0"	12'-11"	6'-9"	28'-8"	Built
250,000	40'-0"	10'-4"	11'-7"	7'-6"	29'-5"	to
275,000	40'-0"	11'-11"	13'-9"	7'-6"	33'-2"	Order
300,000	40'-0"	8'-7"	17'-11"	7'-6"	34'-0"	
350,000	44'-0"	14'-8"	13'-10"	8'-0"	36'-6"	
400,000	46'-0"	12'-2"	14'-9"	8'-8"	35'-7"	
500,000	50'-0"	15'-0"	14'-6"	9'-8"	39'-2"	
600,000	55'-0"	14'-4"	14'-0"	10'-0"	38'-4"	
750,000	60'-0"	15'-11"	12'-7"	11'-6"	40'-0"	
1,000,000	65'-0"	21'-8"	15'-9"	11'-0"	48'-5"	

Table IV—Railroad Type Tanks



Capacity in U.S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H
20,000	15	10 9	16 2	
25,000	15	14 7	19 11	Any
30,000	17	12 7	19 0	height
40,000	19	13 1	20 6	from
50,000	21	13 1	21 1	15' 0"
60,000	24	10 1	20 3	to
75,000	24	15 1	23 10	40' 0"
100,000	28	13 5	23 7	in
150,000	28	14 2	24 7	multiples
200,000	36	15 1	29 2	of
250,000	38	17 3	33 3	5' 0"
300,000	38	23 11	38 3	

Table V—Toroidal Bottom Tanks



Capacity in U.S. Gallons	Tank Diameter (D) when h = 10' 0" and V=20' 0" ft.	in.	V=25' 0" ft.	in.	V=30' 0" ft.	in.	V=35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built
1,500,000	115	2	102	9	93	9	86	8	to
2,000,000	132	8	118	5	108	0	99	11	Order
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U.S. Gallons	Diameter ft.	Height ft.	in.
50,000	20	21	6
60,000	22	21	6
75,000	24	22	6
100,000	26	25	6
150,000	30	28	9
200,000	34	29	9
250,000	38	29	9
300,000	42	29	3
400,000	46	32	6
500,000	50	34	6
750,000	60	35	9
1,000,000	70	35	0
1,500,000	80	40	3
2,000,000	95	38	3
2,500,000	110	35	6
3,000,000	120	35	9
4,000,000	130	40	9

CHICAGO BRIDGE & IRON COMPANY

Chicago 4.....2198 McCormick Bldg. Los Angeles 14...1455 Wm. Fox Bldg. Houston 1.....5615 Clinton Drive Washington 4.....703 Atlantic Bldg.
New York 6..3390-165 Broadway Bldg. Birmingham 1....1586 North 50th St. Philadelphia 3.....1644-1700 Walnut Street Bldg. San Francisco 11....1283-22 Battery Street Bldg.
Cleveland 15.....2262 Guildhall Bldg. Tulsa 3.....1646 Hunt Bldg.
Plants in Birmingham, Chicago and Greenville, Pa. In Canada: Horton Steel Works, Limited, Fort Erie, Ont.

Bins, Storage
Breeching, Steel
Chutes, Steel
Filtration Plants
Flumes, Iron and Steel
Gas Holders
Hoppers, Steel
Penstocks
Pipes, Riveted Steel
Pipe, Welded Steel

We design, fabricate and erect elevated water tanks, storage tanks and pressure vessels for municipal service. This experience enables us to discuss the advantages of various designs of storage tanks and vessels and to submit estimating figures to municipal officials and water works engineers. If you are planning installations such as those mentioned, write our nearest office stating capacity, location and type of service desired.

RADIAL-CONE BOTTOM TANKS

Radial-cone bottom design tanks were developed to provide large capacity elevated tanks with a low range head. Tanks of this design make possible the storage of as much as two million gallons of water with a range in head of only 25 ft. Where wider ranges are permissable, radial-cone design tanks can be built with depths of 30 to 50 feet.

Radial-cone bottom tanks may be designed with cone, dome, or ellipsoidal roofs, with or without balconies. While cylindrical column construction is preferred by most municipalities, structural towers are also available. The table below shows standard sizes for radial-cone tanks.

A booklet showing various radial-cone installations, is available on request. Write for your copy.

A 1,500,000-gal. Radial-cone bottom, ellipsoidal-roof elevated water storage tank installed at San Antonio, Texas. This unit has a tubular-column tower and no balcony. The radial-cone design permits the building of large capacity elevated tanks with small range in head.

Left, above, a 1,500,000-gal. tank at Manitowoc, Wisconsin. Above, a 500,000-gal. elevated water storage tank at Birmingham, Michigan. Left, a 1,500,000-gal. radial-cone bottom tank at Indianapolis, Indiana.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61'	25'
750,000	76' 8"	25'
1,000,000	87'	25'
1,500,000	106'	25'
2,000,000	122'	25'

Shown below are three ellipsoidal-bottom elevated tank installations, typical of the type which are serving municipalities throughout the country. From left to right: A 50,000-gal. ellipsoidal roof and ellipsoidal bottom tank located at Montrose, Minn., a 500,000-gal. tank at Bristol, Pa., and a 50,000-gal. cone-roof, ellipsoidal-bottom tank at Arthur, Illinois.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

Ellipsoidal-bottom tanks are built in a wide range of standard sizes. Since tanks of this design have relatively large diameters and shallow depths, water pressure variations between upper and lower levels are kept at a minimum. Risers on ellipsoidal-bottom tanks are connected directly to tank bottom, eliminating the necessity of an expansion joint. Ellipsoidal-bottom tanks are available with ellipsoidal or cone roofs.

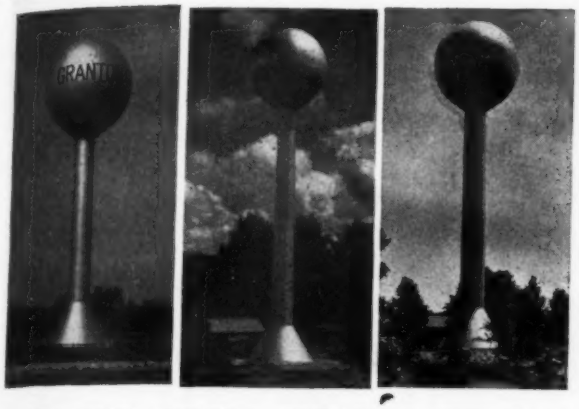
ELLIPSOIDAL-BOTTOM TANK SIZES

Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

HORTON ELEVATED STORAGE TANKS

WASHWATER TANKS . . . FLAT-BOTTOM STORAGE TANKS . . . HORTONSPHERES SEWAGE GAS HOLDERS



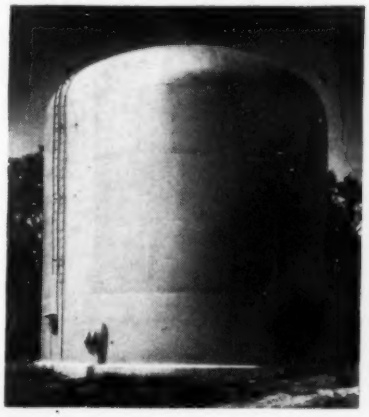
Three typical Watersphere installations are shown above. Their capacities and locations are (left to right): 50,000-gal., Granton, Wisconsin; 75,000-gal., Waterbury, North Carolina; 150,000-gal., Kent, Ohio.

Pressure Vessels, Welded
Reservoirs, Steel
Receivers, Air
Smoke Stacks
Standpipes

Steel Plate Work
Tanks, Elevated Steel
Tanks, Storage
Tanks, Surge
Tanks, Washwater

THE WATERSPHERE

THE Waterspheres shown at left are of new and modern design. They consist of a sphere supported by a single column. The column rests on a cone base which is rigidly attached to the concrete foundation. The smooth surfaces make Waterspheres easier to paint. Waterspheres ranging in size from 40,000 to 250,000-gals. have been installed in many municipalities.



MISCELLANEOUS TANKS

WASHWATER TANKS

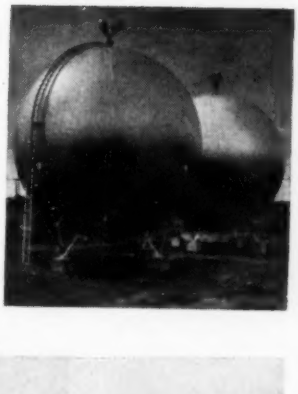
We also build ellipsoidal, radial-cone or special shaped tanks to give the rate of flow and head required for washing filters. The 100,000-gal. washwater tank at the left is located at the Michigan City, Indiana, filter plant.

FLAT-BOTTOM WATER STORAGE TANKS

Shown at right is a 25,000-gal. ellipsoidal roof, flat-bottom water storage tank at Kent, Ohio. We build tanks of this type in any diameter and height to meet your requirements.

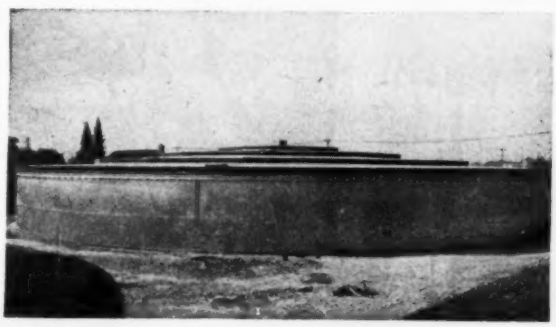
HORTONSPHERES SEWAGE GAS HOLDERS

Utilization of gas produced in the sewage digesters to provide power and heat at disposal plants is an economy-wise practice. A step further is the storing of the excess gas for use when gas production is low. The Hortonsphere at left . . . 36-ft. in diam., operating at 30 lbs. per sq. in. . . was installed at the Duluth, Minn, sewage disposal plant. The twin spheres at right installed at Rock Island, Illinois, are 36 ft. in diam. They hold 50,000 cu. ft. each and operate at 50 lbs. pressure. We also build the lift-type gas holders.



RESERVOIRS

In mountainous or hilly areas, natural elevations can sometimes be used to provide gravity water pressure. We build flat-bottom steel reservoirs for this type of service in standard sizes or special deigns to meet your requirements . . . of riveted or welded construction . . . with or without roofs.



Right: One of two 2,300,000-gal., all-welded steel reservoirs installed at Alhambra, California.

R. D. COLE MANUFACTURING CO.

Est. 1854

Tanks, Towers, and Steel Plate Work
NEWNAN, GA.

5,000 TO 2,000,000-GALLON WATER TANKS

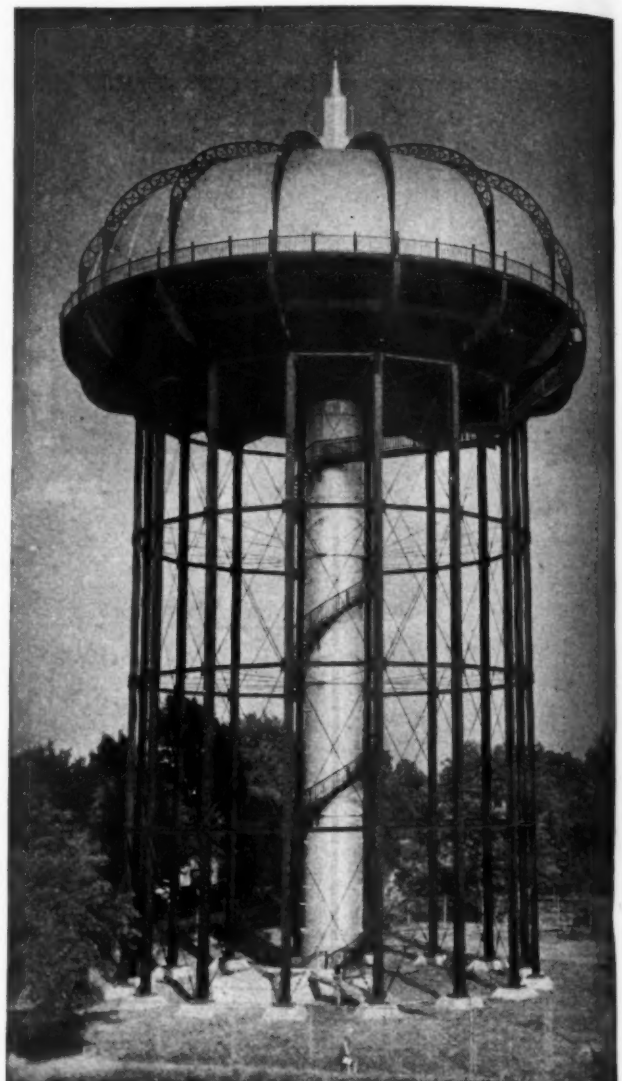
All shapes and sizes—The R. D. COLE MANUFACTURING CO. has developed a complete line of elevated steel tanks for water supply, both for domestic service and sprinkler requirements, ranging in capacity from 5,000 to 2,000,000 gallons.

The designs include the standard Hemispherical Self-supporting Bottom, the "Cole Ovaloid," Standpipe and many individual styles involving architectural treatment to satisfy local conditions, or to provide special shapes for advertising purposes.

STORAGE TANKS

Pressure tanks for storage of gas from digesters at sewage disposal plants so that excess output at peak loads can be used during off-peak periods. Chemical storage tanks, hot water storage tanks, tanks for bulk storage of oils and gas.

Designs Available for Any Service



1,000,000-Gallon "Cole-Shallow Depth" Tank

CONSTRUCTION FACILITIES

Fabricated Steel Plate—The R. D. COLE MANUFACTURING CO. has a fully equipped plant for the fabrication of riveted or welded steel plate. In addition to the construction of its regular line of horizontal return tubular boilers, oil storage tanks, tubular heaters, etc., the company is prepared to construct special tanks and apparatus of any specified metal plate.

Alloys and Lining for Processing Apparatus—The facilities and experience of the company enable it to fabricate special apparatus of all kinds for the processing industry using alloy steel plates, stainless steel, nickel-clad steel, etc., or linings such as lead, tin, nickel or Monel.

MAINTENANCE OF ELEVATED TANKS

By JOHN M. PERRYMAN
Engineer, R. D. Cole Manufacturing Co., Newnan, Ga.

TANKS and towers are an important part of most water supply and fire protection systems, and should receive the same care and attention as other important parts of such systems.

It is generally known that corrosion of iron and steel is a silent enemy, working during both war and peace through all the years. The conversion of steel into iron oxide or rust is Nature's course in returning iron or steel into its original state.

Air and water coming into contact with steel starts this cycle of returning iron and steel to rust. Rust occupies more space and also weighs more than the steel destroyed, for it consists of hydrous iron-oxide which is 54 per cent iron, 20 per cent oxygen and 26 per cent water. Due to capillary action water will climb a rusty steel tank shell or column, regardless of its height. Corrosion of steel tanks can be caused and accelerated by the presence of acid fumes in the air, and particularly are tanks in large industrial areas thus affected. Also tanks located in areas of high humidity and along coastal waters, where high salt bearing vapors are present, are subject to accelerated rusting.

This Tank Has a Nice New Coat of Paint, But— an inspection by a qualified man would have avoided a dangerous condition. In very poor condition, the base of this recently painted tank was not given needed attention. It was not cleaned properly before painting and the base plate should have been grouted to shed water, prevent corrosion and frost spalling.

Another Bad Base Condition The base structure has been cleaned and painted but the brick foundation is badly in need of repairs. This picture also reveals the hazardous practice of removing the lower tower rods.

Surface Preparation

Tanks should be protected at all times from the elements that cause rust, using a paint that will protect the surface and present a favorable appearance. Steel can be protected at a reasonable cost by the use of rust inhibitive steel coatings. In preparing the surface the use of expensive sand-blasting is not necessary, nor chipping to the bare metal. The use of hand or power driven wire brushes is really all the preparation that is essential. The simple method of removing loose paint, scale and dirt by hand brushing, then applying a rust-inhibitor to seal the steel from the atmosphere will protect and prolong the life of your structure.

Loadings on Tower Members

As an example of the heavy loadings, on the tank tower structure, I might mention the 2,000,000 gallon tank in Charleston, S. C. The water and metal loading exceeds the weight of 6,000 Ford cars, and the 100,000 gallon tank at Mt. Pleasant, S. C., amounts to 325 Ford cars. You can see from this that the tower load involved in overhead tanks is appreciable, and must be dealt with according to a scientific business like procedure.

The Inspection

To assure long life and prevent, as near as practicable, the formation of rust, and in addition provide a safe structure, the tank should be drained completely, allowed to dry, and inspected by a competent inspector at intervals not to exceed five years.

These inspections should be made by no other than a skilled man who is thoroughly competent to detect weaknesses and pass upon their importance. This is not a matter which can be left to transient steeplejacks or traveling inspectors of unknown ability and integrity—the man should be a structural engineer. In locations where the water is highly aerated or contains particularly corrosive elements, the examination should be made more frequently than once in five years.

When an inspection is to be made, the fire chief and others dependent upon the water supply should be notified in order that they may not be dependent upon the tank for extra head and volume during the planned outage.

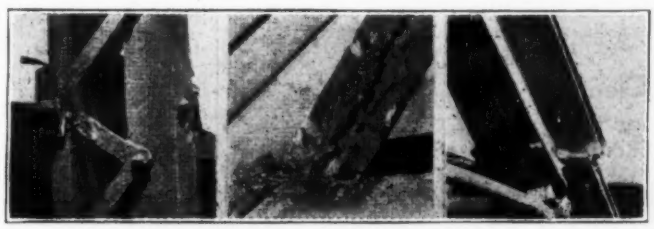
What to Look For

The inspection should consist of: first, an examination of all ladders for safety; especially examine for missing connecting bolts, conditions of lugs and rungs, etc. The revolving ladder on the roof should be inspected for a poor connection at the finial, also the ladders on the inside of the tank and rise should come in for thorough examination. Check condition of the roof and spider, and be sure that it will prevent the entrance of birds and other harmful matter, and that it will safely withstand sudden high winds. Examine the tank proper for loose scale and leaky rivets and seams.

The balcony floor is designed to resist the thrust of the columns and should be perforated at proper places so that water will not stand on the floor. Examine the hand rail for safety, also all rods, turnbuckles, clevises and pins.

Repairs and Replacements

Before repainting you should be certain that all badly corroded parts have been replaced or properly repaired. Look *under* the clevis pins and rod loops on your tank. The top side may be in excellent condition, but *the underside and partially hidden section may be found to be in a dangerous condition.* Examine the back surfaces of lattice bars, anchor bolts, the inside of boxed channel columns, pockets where batten plate connections and column bases form pockets for collecting trash and water without proper drainage. These enclosures may be cleaned and



Some Bad Order Specimens
(Left) Lattice bars completely eaten away where building roof contacts the tower leg.
(Center) Another specimen of badly corroded tower leg.
(Right) This obsolete style of tower leg has all but failed. It buckled under the full load weight.

painted, then filled with concrete to a proper level at the top and shaped to shed water. Base plates should be grouted with sand and road oil mixed, or with asphalt.

Where angles or othter structural sections are separated by narrow spaces, rust can usually be removed by using narrow, bent scrapers, and the sides of the angles facing the narrow space may be painted with a spray gun. The present day manufacturer of elevated tanks endeavors to offer a tank design using open sections that can be readily inspected, cleaned and maintained.

If structural members of details affecting the strength of the tower are found to be in a condition such that they must be replaced, they should be renewed by a *recognized* tank designer, fabricator and *skilled* erectors.

Diagonal wind rods should not be removed for cleaning and repairing, except when the tank is empty and on a calm day, and then only when adequate provision has been made by means of struts and guy wires to prevent a possible collapse of the structure.

An Important Hole to Keep Open

The arrow points to the deep hole in the boxed-in column section to drain water from this type of base.

The bases and base plates must be examined, and if the base is so built that it holds water (see illustration), drill a 1¼-inch hole through the channel boxed section to permit drainage. Trash should be removed at regular intervals. The base plates should be grouted with a mixture of sand and asphalt so water cannot run under the plates. The grout should taper off from top edge of plate to concrete pier.

There are a number of elevated tanks built with auxiliary tanks of smaller capacity suspended underneath, also flat bottom tanks built on supporting grillage. When these tanks are inspected, look for badly corroded suspension rods and connections to the tank. They quite often are found in a dangerous condition. The steel grillage on flat bottom tanks is subject to heavy corrosion and only on careful examination will you find those connections that have become unsafe. There have recently been some tanks found in dangerous condition that were originally built without balconies and not sufficient reinforcing at the column connections. The shell plates have actually broken, due to over-stressing and fatigue of the metal.

Concerning Rivets and Seams

Much has been said about leaking rivets and seams. The facts are that in most cases the importance of this is exaggerated and sometimes used by unscrupulous repairmen as an entry and excuse for expensive repair work.

Loose rivets can be caulked just as effectively as can leaky seams. Don't let anyone tell you that because the head of a rivet is badly pitted that it must be removed and a new one driven. Remember that a rivet head is to hold the plates firmly together, and other than holding a small tension between the plates, a corroded head does not seriously impair the strength of your structure. *It is the shank of the rivet that really does the job.* Furthermore, when a rivet is knocked out, you loosen at least eight additional adjoining rivets, thus a larger repair job has been created. Be careful!

Cleaning

After all of the above procedure has been carried out, the tank should be thoroughly cleaned both inside and outside, as well as the tower and other parts of the structure. Paint or mill scale which adheres firmly to uncorroded steel should *not* be removed, but these surfaces should be cleaned to remove all loose dirt or sediment. Where extensive pitting of the steel beneath several coats of paint is encountered, this portion should be vigorously wire brushed with a power tool to prepare properly for the new coat of paint.

If the tank has a large steel riser (36-inch diameter or larger), all sediment can be removed from the base by the means of the washout valve in the base of such risers. However, if the tank has a small cast iron or steel riser of from, say, 8 to 12 inches, it will be necessary to bail the sediment from the bottom of the tank, since these tanks are in general without washout valves.

Remember to repack the expansion joint and replace all brittle and leaking gaskets at manholes. Frostproof casings should be repaired or replaced; or, even better, remove both pipe and casing and have a 36-inch steel riser installed in its place if the size of the installation will justify it.

Painting

Best results from painting are obtained when the outside temperature is above 50 F. and the temperature of the paint and surface to be painted are the same. Painters should be cautioned not to allow trash, paint or other material to drop down the riser while they are cleaning or painting. A sheet of heavy paper may be tied over the small riser, or a deck may be built across a large riser pipe.

Interior

During the summer it is best to paint tank interiors at night in order to avoid uncomfortably high temperatures. Paint dries more quickly on the inside if the manhole cover is removed and the roof hatch is left open. Forced air circulation has a definite advantage in expediting the painting job, and it should be remembered that forced circulation adds greatly to protection of the painters and accelerates drying.

It is recommended that the inside of the tank, riser and underside of the roof be painted with two complete coats of red lead and a final coat of black interior tank finish. This finishing coat should be of the type that does not impart any taste, odor, or discoloration to the water.

The coat of black interior tank finish is actually to protect the red lead, and, of course, the red lead is to protect the steel.

Exterior

Paints tend to loose their imperviousness when submerged in water for long periods, such as on the inside of tanks. It is suggested that 10 per cent by weight of litharge be added to resist the softening action and hasten the drying. The litharge may be mixed in a small amount of linseed oil and then added to the red lead as required.

The outside should be painted with a coat of either red lead or gray lead, followed by two coats of aluminum. It is also suggested that you paint all abraised surfaces with two touch-up coats prior to the finish painting with aluminum.

For best results, the final coat inside the tank should be allowed to dry *at least one week* before admitting water.

Safety and Cleanliness

Paint thinned with naphtha, benzol, toluol or other liquids which give off toxic vapors are hazardous to life when used in confined spaces such as inside of a tank. They should be used only by experienced painters who are thoroughly familiar with their proper applications and the hazards involved. Forced air circulation inside the tank and gas masks are essential where such dangerous materials are employed.

After painting, particular care should be taken to make sure that all planks, scaffolding, rope, paint cans, brushes, and other material are removed from inside the tank and riser. This having been done, you should refill the tank, sterilize it in accordance with the Board of Health requirements, and restore service as soon as possible, considering good workmanship and proper drying as the first essentials.

Foundations should be examined, and if showing signs of deterioration should be carefully pointed up with a cement mix consisting of one part cement and one part of sand. There have been a number of foundation piers built of brick or stone. These should receive extra attention.

A typical specification for tank painting follows, and we believe that it will eliminate any possibility of the tank owner suffering from some unscrupulous contractor, holding him responsible for charges other than cleaning and painting, unless such extras are authorized in writing. Your attention is further directed to the practice made by most tank fabricators and erectors of making tank inspections at a nominal charge and

giving a written report of work that, in their opinion, is actually necessary.

REPAINTING ELEVATED TANKS
(A Pattern for Specifications)

Bids are to be received for the furnishing of the necessary labor, tools, equipment and materials to clean and paint Elevated Steel Water Tank and on a steel tower elevating the bottom Steel Tower of ——— gallons capacity —— ft. —— in. above top of foundations, and/or Flat Bottom Steel Water Reservoir of ——— diameter x ——— height.

General: The inside of the tank proper and underside of roof is to be carefully examined and all loose paint, scale, rust and blisters are to be removed with scrapers and power wire brushes and the surfaces thoroughly dried. Paint or mill scale which adheres firmly to uncorroded steel need not be removed, but the surface should be cleaned to remove sediment and dirt. If there is extensive pitting of the steel, this is to be brought to the attention of the inspector for whom the work is being done.

The spider rods, inside ladder, or any oher inside structural details, such as the inside of the large steel riser pipe, is to be thoroughly cleaned as previously mentioned before any paint is applied.

All dirt and sediment collecting at the base of the riser is to be removed.

Any brittle or leaking gaskets at the manhole, washout valve or other openings are to be replaced with new gaskets of equal or better materials.

The inside of the tank and large steel riser after being prepared as heretofore mentioned and approved by the inspector, are to be given one coat of red lead paint with 10 per cent by weight litharge added to offer resistance to softening action of the water and dry more quickly. After this red lead coat has become thoroughly dry, a coat of black interior tank finish paint is to be applied on the inside for the finish coat.

The outside of the tank is to be examined and cleaned as indicated for the inside, with especial attention being given to those parts of the tank structure which are difficult to clean, such as around the clevice pins and end of diagonal wind rods, anchor bolts or back surfaces of lattice bars or columns, inside channel columns near foundations, inside surface of members composed of angles which are separated by thin lattice bars, washers or short pipe.

If members or details effecting the strength of the structure are found seriously corroded, this should be brought to the attention of the inspector. Diagonal wind rods or other members should not be removed for cleaning, unless the tank is empty and adequate provision is made to prevent the structure from collapsing.

After the outside has been thoroughly cleaned, a touch-up coat of red lead is to be applied to all surfaces where the paint has been removed, and then the entire outside of the tank and tower is to be given two coats of aluminum paint of color selected by the purchaser and of a kind made purposely for application to outside of steel water tanks.

The contractor for this work is not to apply any paint, unless the outside temperature is above 50 degrees, and paint and surface of the steel should be approximately the same temperature.

Provision is to be made for the safety of the men, providing proper ventilation for working on the inside, and comply fully with all local and state laws; Workmen's Compensation, Public Liability and Property Damage Insurance are to be carried with $10,000.00 and $25,000.00 limits.

Certified copies of policies in force to be attached to contract.

The contractor is to employ only skilled elevated tank painters, and no other work except the above cleaning and painting is to be done, except with written approval.

Upon completion of the painting, the contractor is to remove or dispose of all rubbish or other unsightly material caused by their operation and leave the premises in as good condition as it was found.

Terms of payment: Net cash on completion and acceptance of work.

Additional Comments

Tanks with small cast iron risers and wooden frost casings should be examined and expansion joints repacked.

If hot water or steam pipes are in poor condition, they should be replaced.

Consult your insurance company and advise them when the tank will be out of service and length of time out of service.

If the tank is a municipal water supply unit, notify the local fire authorities when the tank will be out of service, so they will not be dependent on this volume of water for fire protection.

MAKING PIPE BUSHINGS FROM STANDARD PIPE

A Handy Kink

DO YOU know that first class pipe bushings can be made out of standard pipe? Many users of pipe don't know that it can be done. Or, if they know that it can be done they don't know the correct size of drill to use for tapping. I have occasionally made bushings out of pipe, but each time I found it necessary to first look into my handbook for the drill size to use and that is so much trouble that it is frequently easier to go to the store and buy a new bushing. Recently, though, I collected all of the data together for all bushings that can be made out of ordinary sizes of extra heavy and double extra heavy piping, compiled the figures in tabular form, and here they are.

For example, to bush from ¼" to ⅛" get a piece of ¼" extra heavy pipe sufficiently long for cutting the outside thread. Then cut the end off to the desired length, drill or ream with a 21/64" drill (diameter of drill 0.328") and then tap with a ⅛" pipe tap. That's all there is to it.

This accompanying table tells the complete story for all ordinary sizes: Note that in one case, ⅜" to ¼", the internal diameter of ⅜" extra heavy pipe is such that no drilling is necessary.

Note also that in bushing from ½" to ⅜" either extra heavy or double extra heavy piping can be used.

To Bush From	Use This Size Pipe	Use This Size Drill or Reamer
¼" to ⅛"	¼" X	21/64" drill = 0.328"
⅜" to ¼"	⅜" X	None.
½" to ⅛"	½" XX	21/64" drill = 0.328"
½" to ¼"	½" XX	27/64" drill = 0.422"
½" to ⅜"	½" XX	9/16" drill = 0.562"
½" to ⅜"	½" X	9/16" drill = 0.562"
¾" to ⅜"	¾" XX	9/16" drill = 0.562"
¾" to ½"	¾" XX	11/16" drill = 0.688"
1 " to ¾"	1 " XX	29/32" drill = 0.907"
1¼" to 1 "	1¼" XX	1/18" drill = 1.125"
1½" to 1 "	1½" XX	1/18" drill = 1.125"
1½" to 1¼"	1½" XX	1-15/32" drill = 1.468"
2 " to 1½"	2 " XX	1-23/32" drill = 1.72 "
2½" to 2 "	2½" XX	2- 3/16" drill = 2.187"
3 " to 2½"	3 " XX	2- 9/16" drill = 2.562"
3½" to 3 "	3½" XX	3- 3/16" drill = 3.187"
4 " to 3½"	4 " XX	3-11/16" drill = 3.688"
4½" to 4 "	4½" XX	4- 3/16" drill = 4.187"
	X = extra heavy pipe. XX = double extra heavy pipe.	

CLEANING, PAINTING, AND PROTECTING STEEL WATER TANKS

By JOHN M. PERRYMAN
Engineer, R. D. Cole Mfg. Co., Newnan, Ga.

STEEL water tanks and towers should receive careful annual inspections and not suffer from neglect. Some estimates of cost, intended to provide ideas of the amounts involved to properly protect water tanks of various sizes, are given in this article.

Leading designers, fabricators and erectors of steel water tanks are in position to offer inspection service and competent advice as to necessary work that may be required to maintain or place tanks in the best of condition. This service will usually cost from $100.00 to $150.00, depending upon the location.

Paint has been and still is the proven method for the protection of steel, although, through research and experience, other methods are being used. Therefore some are mentioned for your consideration.

Even the best paints will not adhere to rusty steel without the steel having been properly cleaned of all loose rust, grease and old loose paint. Thorough wire brushing is all that is really necessary, although in badly corroded structures more severe methods may be required, such as sand-blasting. See specifications at end of this article.

The ideal time to clean, paint and repair is during the late spring and the early fall months, and never when temperatures are likely to be less than 50 degrees, and the ideal is from 60 to 70 degrees.

Good Paint Is Good Economy

The use of good paint is good economy. Since labor is the governing factor in the cost of painting, amounting to approximately 80 per cent of the total cost, the use of the better grades of paint adds little to the final cost.

The American Water Works Association and some insurance underwriters have published specifications for proper methods of tank cleaning and paints that are satisfactory. Therefore it is suggested that you communicate with them or with the manufacturer of your elevated tank, in order that you may secure the best available information before proceeding with the cleaning and painting of your water tanks.

A fact to remember is to "repair" before painting, so it is desirable that you secure the advice of experts before proceeding with your painting. When experts are mentioned, do not be misled by false or misleading statements. Remember the loads involved in water tanks of the elevated type are highly concentrated—and the advice of so-called "steeple-jacks" that are not professional engineers cannot, therefore, be relied upon, as usually they do not have knowledge of the stresses or the methods of calculating stresses to advise you fully as to the strength or weakness in a steel tank. It is suggested, therefore, that you ask for credentials or other evidence as to one's ability to pass judgment on tank details, as this is highly important.

CHART NO. 1

Gallons of Paint Required Based on 100-ft. Towers

	50,000 Gals.	75,000 Gals.	100,000 Gals.	150,000 Gals.	250,000 Gals.	500,000 Gals.
First Coat Inside....	8	10	12	15	25	50
First Coat Outside...	12	14	17	22	35	70
Second Coat Outside.	12	14	17	22	35	70
*Riser, per coat.....	3	3	3	3	3	3

Note: The 3 gallon requirement is for 3′ diameter risers. For 4′ diameter riser, add 3 gallons; for 5′ riser, add 6 gallons per coat.

Furthermore, before entering into a contract be certain that all work to be done has been agreed upon in writing, and that no hidden clauses are in the contract which entitles the person or persons doing the repair work to proceed with additional repairs or replacements without written advice and predetermination of cost.

Estimating Paint Requirements

Now let us consider quantity of paint involved to properly paint your tank. Chart No. 1 gives the average quantity of paint required, and I believe that this is fully self-explanatory. This chart is for your guidance and should take care of all popular sizes of elevated steel water tanks.

Paints of the highest quality can currently be procured at about the following prices:

Red lead—$4.50 per gallon.
Black interior water tank paints—$3.50 per gallon.
Aluminum and other high grade exterior paints for steel structures at approximately $4.00 per gallon.

Sample Estimate

You may refer to Chart No. 1 and secure therefrom the amount of paint required for your tank, and then total the approximate cost as illustrated:

Take, for example, 100,000-gallon elevated tank together with a steel tower 100 feet high and a 3-foot diameter steel riser and calculate as follows:

1—Inside red lead (15 gals.) @ $4.50	$ 67.50
2—Inside black paint (15 gals.) @ $3.50	52.50
3—Outside red lead (5 gals.) @ $4.40	22.50
4—Outside aluminum (40 gals.) @ $4.00	160.00
Total for materials	$ 302.50
Add for labor and incidental cost, four times the cost of paint	1210.00
Total cost for doing a nominal amount of wire brushing, both inside and outside, replacing manhole gaskets, and stopping any small leaks (not to exceed 10), total cost	$1512.50

When Using Cathodic Protection

In lieu of painting the tank complete on the inside you may calculate the approximate cost of painting the underside of the roof and top ring on the inside of the tank and the outside of the tank to be painted with two coats of paint and for the inside using cathodic protection. The cost will be about as follows:

Inside red lead (5 gals.) @ $4.50	$ 22.50
Inside black paint (5 gals.) @ $3.50	17.50
Four times materials for labor	160.00
Scaffold	50.00
Cathodic unit installed (see Chart No. 2)	600.00
Total	$850.00

And to the above you must add the cost of the outside painting (see first tabulation, items 3 and 4):

Paints for outside	$ 182.50
Four times material for labor	730.00
Total cost of painting the outside	$ 912.50
Cost of painting outside of tank and tower, painting underside of roof and installing Cathodic Protection on inside	850.00
Total cost	$1762.50

Bituminous Enamel Interior Coating

Another method of protecting the inside is with the use of one coat of bitumastic priming solution and one coat of bitumastic enamel on the inside of the riser, the bottom and shell of the tank and painting the underside of the roof two coats of bitumastic solution. The approximate cost of doing this work is about $1350.00 for applying bitumastic enamel on the inside and the cost of painting the outside of the tank, $912.50, giving a total of $2262.50.

From the above illustrations and using charts No. 1 and No. 2 you can approximate the cost of cleaning and painting your tank, applying cathodic protection to the inside or using the bitumastic enamel.

In using the above estimates, remember excessive cleaning, repairs and replacements *are not included* in the estimates of cost outlined, nor does the information given outline the advantages or peculiarities of any of the principal methods of giving protection to your tank; nor do they include estimates of life expectancy or protection, upkeep of operating devices and operating cost of the electrical protective devices.

CHART NO. 2

Cathodic Protective Units

The approximate cost of Cathodic Protection, not including cost of cleaning the inside of tank, nor painting the underside of the roof and top shell ring:

50,000 gallon tank	$500.00
100,000 gallon tank	600.00
250,000 gallon tank	800.00
500,000 gallon tank	1000.00

Cost of painting underside of roof and top shell ring:

50,000 gallon tank	$225.00
100,000 gallon tank	250.00
250,000 gallon tank	400.00
500,000 gallon tank	600.00

Approximate cost applying one coat Bitumastic Solution and one coat Bitumastic Enamel to riser, bottom and shell and two coats Bitumastic Solution underside of roof:

50,000 gallon tank—3′ riser	$1200.00
100,000 gallon tank—3′ riser	1350.00
250,000 gallon tank—4′ riser	2300.00
500,000 gallon tank—5′ riser	3500.00

Cleaning, Repairs and Painting Specifications

The reader is referred to specifications given on page R-77, *Water Works and Sewerage*, June, 1944.

ROSS VALVE MFG. CO., INC.

TROY, NEW YORK

AUTOMATIC CONTROL & PRESSURE REGULATING VALVES

***For* Water Works and Fire Departments**

For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4" to 30" are guaranteed for services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

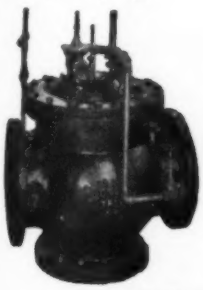
Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Installed in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller



Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

Model 40 FWR—External Pilot Operated, Semi-throttling--for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½" hose connections delivering independently from shutoff to full pressure and a fifth connection 2½" to 3" delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Line: Internal Packing Replaced Through Top of Valves.

GOLDEN-ANDERSON VALVE SPECIALTY CO.

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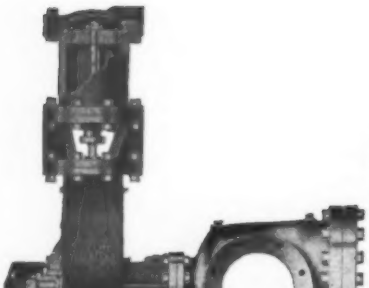

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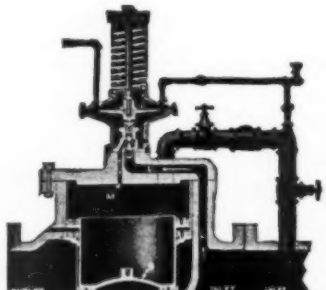

ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24″.

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Automatically maintain uniform water levels in tanks, standpipes, etc.

Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24″.

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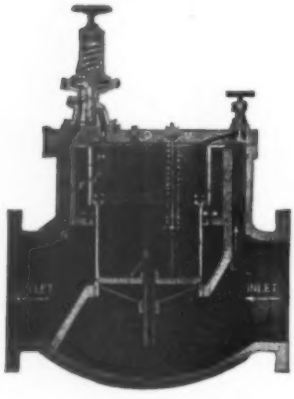
Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24″.



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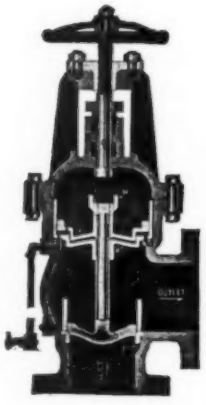
Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24″.



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Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12″ in angle, globe or elbow patterns.

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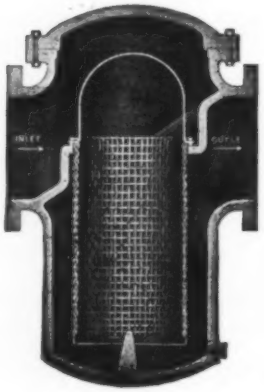

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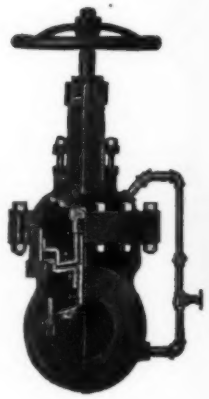
The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12″ sizes.



CATHODIC PROTECTION OF STEEL SURFACES IN CONTACT WITH WATER

By LEON P. SUDRABIN
Chemical Engineer, Electro Rust-Proofing Corp., Dayton, Ohio

PART I—Basic Principles and Controlling Phenomena

THE establishment of the most satisfactory method for mitigating the corrosion of steel surfaces in contact with natural waters[1] in the pH range of 4.5 to 10.0 has been a challenge to all engineers who design and operate steel structures such as clarifiers, filters, water storage and heating tanks which come in contact with this environment. The method selected for retarding the wastage of metal by corrosion is usually based on any one or a combination of the following procedures: (1) use of protective coating; (2) the adaptation of metals and alloys which resist the corrosion environment encountered; (3) chemical treatment of the water to make it less aggressive; (4) cathodic protection, which subdues galvanic corrosion electrically.

In the water works field, cathodic protection as a method of corrosion control is a relative newcomer, the first application to water storage tanks probably being made in 1936.* Since that time cathodic protection has established itself, when properly applied, as being a practical method of protecting submerged steel surfaces.

What Cathodic Protection Is

In the simplest sense, cathodic protection consists of stifling the flow of current which accompanies electrochemical corrosion by projecting a current flow through the corroding media to the metal where it becomes superimposed on the metal surface to be protected.

This definition conforms with that given by earlier research workers in the field of corrosion, and its thought will be developed throughout this paper.

When compared with other methods of corrosion control, properly understood and properly applied, cathodic protection has advantages which justify its consideration as the solution of many corrosion problems.

(a) In many cases installations can be made and placed in operation without taking the equipment to be protected out of service. This is of particular importance in water tanks used for fire protection, water systems where there is only one head tank or in other equipment where an outage would interfere with production.

(b) Surfaces to be protected do not require special preparation. Old paint films and most scale and corrosion products actually reduce current density requirements for complete protection.

This eliminates the necessity of sand blasting, flame cleaning or wire brushing to remove the old coating and corrosion debris, drying of the exposed surface and providing adequate setting time for a protective coating before contact with the water, in ordor to obtain a satisfactory protection for underwater surfaces.

(c) The use of an adequate current density to take care of the cathodic processes on the surfaces exposed to the corroding media will give complete protection by maintaining protecting effect continuously on the metal surface. This may be compared with the development of failure in most protective coatings which become focal points of accelerated corrosion, resulting in deep pits before a new covering can be applied.

(d) Cathodic protection requires very little maintenance and supervisory attention.

(e) Cathodic protection can be economically justified when compared with other methods of underwater corrosion control.

(f) The chemical nature of the bulk of the water is not altered by cathodic protection.

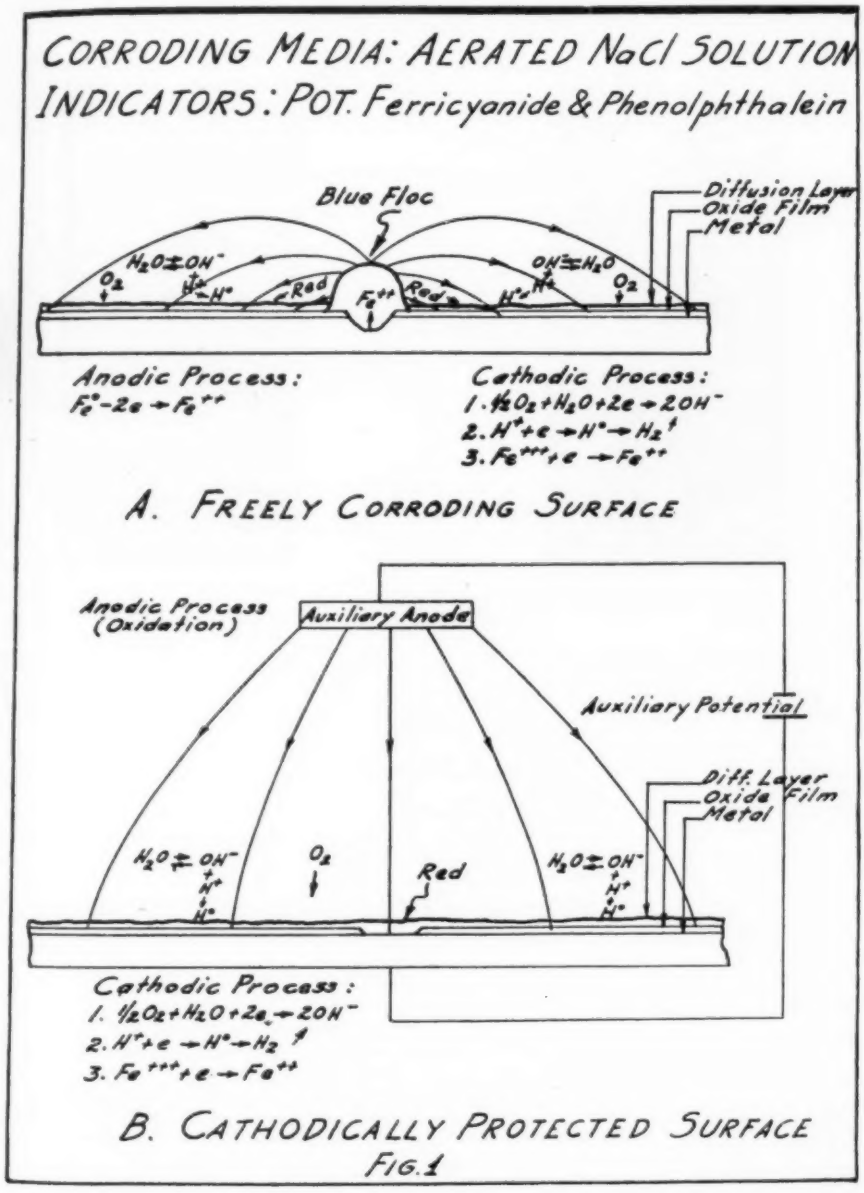


Fig. 1 (A & B)—Schematic Illustration of Chemical Reactions at the Face of a Freely Corroding Surface and One Which Is Receiving Cathodic Protection.

*"A New Method of Tank Protection"—O. B. Hess, Supt. of Water, St. Clairsville, Ohio (*W. W. & S.*, Nov., 1938) is seemingly the earliest published report on cathodic protection applied to water tanks.

Background

The idea of cathodic protection is not all new, since Sir Humphrey Davy[2] in 1824 observed that a metal "...if it could be rendered slightly negative, the corroding action of sea water upon it would be null..." and he "...thought of using voltaic battery..." to supply the current flow to the metal surface.

Practical limitations of the voltaic cells in those days prevented Davy from using them as a means of motivating current flow to large surfaces to be protected; however, he did attach zinc plates to these metal surfaces and protected them by the flow of current generated by the potential difference in the zinc-metal couple. The zinc plates were not effective over large areas. The most complete protection occurred adjacent to the zinc and rapidly diminished in effectiveness as the distance from the zinc was increased.

Around 1912 Cumberland[3] in England, and in the early 1920's Kirkaldy[4] in the United States, made use of direct current for corrosion control and the prevention of scale and formation in surface condensers and boilers. In his application of cathodic protection Cumberland installed anodes of iron mounted on insulated supports in the water boxes of the condenser. By means of direct current from a dynamo he caused current flow from the iron anodes through the sea water to the surfaces to be protected.

The Kirkaldy system was similar to the Cumberland system and was based on the idea that any metal which was made sufficiently cathodic to eliminate all local voltaic or galvanic couples would neither corrode nor permit scale to develop.

Within the last two decades cathodic protection[5] has been used for underground pipeline corrosion control and has probably attained its greatest commercial application in this field, particularly in the petroleum and natural gas industries.

Although the art of cathodic protection is quite old, its practical application has until recent years outdistanced the fundamental engineering data available for design. In order to properly design a cathodic protection installation it is necessary to thoroughly understand the corrosion mechanism itself, the factors in the corrosion environment which govern current density requirements, the fundamentals of electrode materials and design, the economic considerations involved in the initial and operating costs, sources of potential for motivating current flow to the submerged metal surfaces and hazards of the improper use of electric current. These are only a few of the considerations involved in the engineering design of a cathodic protection installation for a particular corrosion problem and indicate that this work should be done only by engineers experienced in the application of cathodic protection.

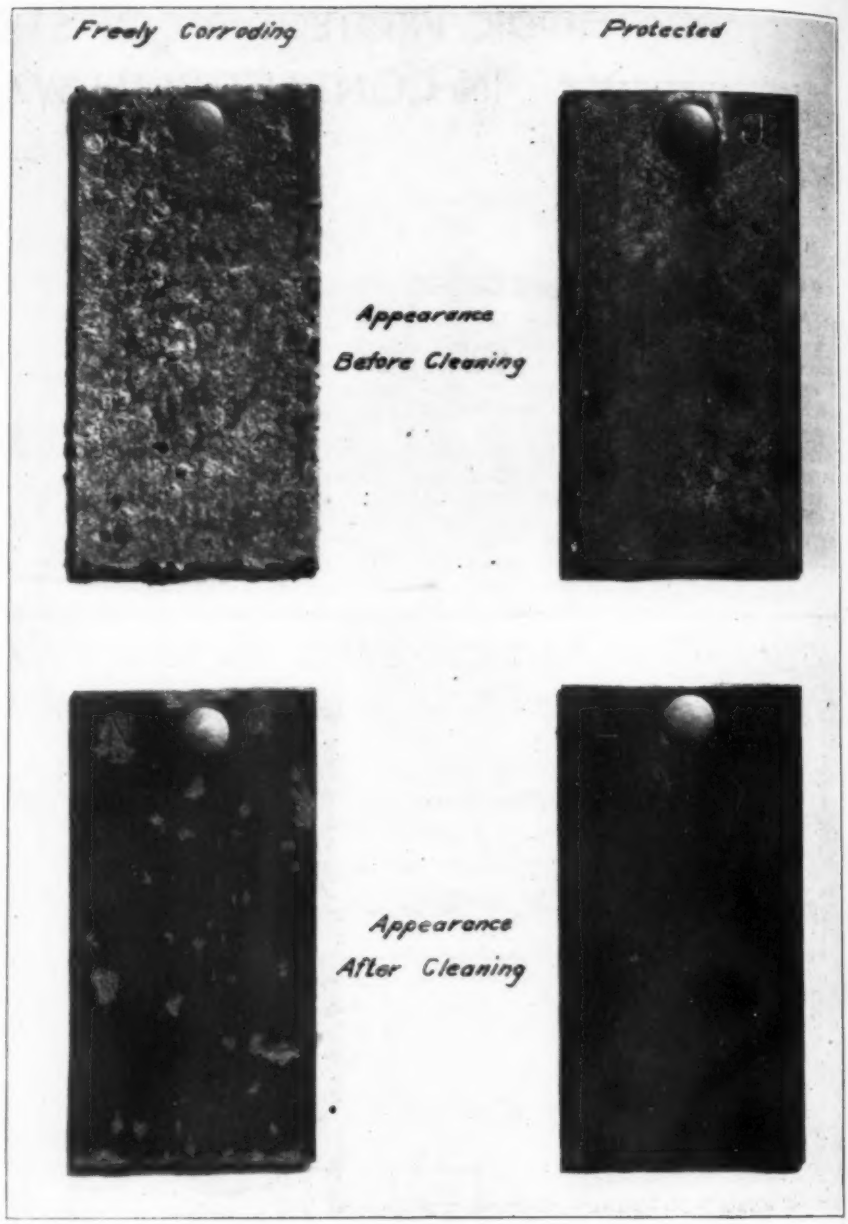


Fig. 2—Freely Corroding and Cathodically Protected Test Specimens from a Dorr Clarifier. (Left—Freely corroding pieces before and after cleaning; right—protected pieces before and after cleaning. Note chalky deposit on plate J before cleaning. Note pitmarks on plate N after corrosion products seen on plate G had been removed.)

Corrosion Mechanism

In order to visualize the manner in which a current flow through the corroding media (water) to a steel surface will protect the metal, the mechanism of electrochemical corrosion should be considered and particularly the factors governing the rate of corrosion.

The localized type of attack illustrated by the development of pits on freely corroding steel surfaces exposed to aerated natural waters (Fig. 2) has been shown to be related to the flow of current resulting from differences in the tendency for the metal to enter the solution in contact with it. Non-uniformities of the metal surface or of the solution in contact with the metal can cause these differences in potential. In practice (1) differential thermal treatment, (2) localized failures of the protective oxide film, (3) differential concentration or nature of the corroding media, (4) differential aeration and (5) dissimilar metals generally determine the location and intensity of the corrosion current.[6]

The electrochemical theory of corrosion proposed in 1903 by W. R. Whitney[7] has become the basic concept of most corrosion phenomena in electrolytes. He associated corrosion with the flow of electricity resulting from the loss of two electrons by each iron atom leaving the crystal lattice of the metal and entering the solution as a ferrous ion at the anodic or most electronegative areas on the metal surface.

$$[Fe^{\circ} - 2e \rightarrow Fe^{++}]$$

This equation pictures the solid metal going into the soluble state involving ionization.

At the cathodic or less electronegative areas, the electrons (e) released by this process are accepted by an equivalent number of hydrogen ions at the metal-solution inter-face where they are reduced to hydrogen atoms. By reducing the hydrogen ions to hydrogen atoms at the more cathodic areas the hydroxyl ions, which result from the dissociation of water, concentrate there and increase the pH.

$$(1)\quad 2H_2O \rightleftarrows 2H^{+} + 2OH^{-}$$

$$(2)\quad 2H^{+} + 2e \rightarrow 2H^{\circ}$$

This process if undisturbed develops sufficient counter potential (polarization) on the cathodic areas in airfree neutral waters,

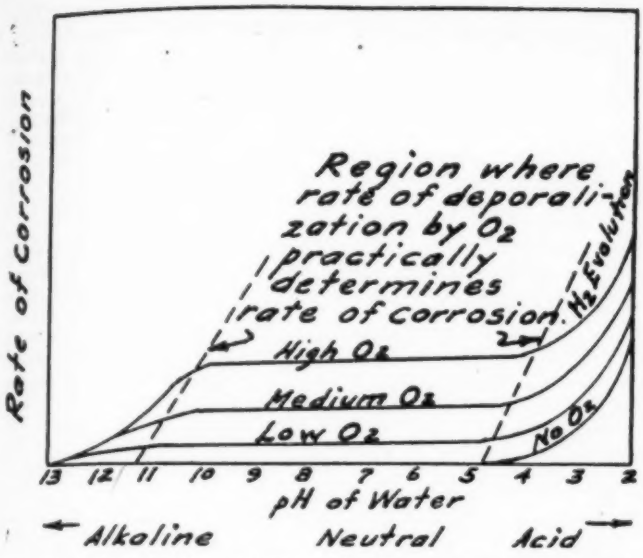


Fig. 3—Effect of pH on the Corrosion Rate of Iron at High and Low Dissolved Oxygen Content of the Water.—(Wilson, 1923).

to stifle further deposition of hydrogen ions and in turn retard solution of metal at the anodic areas.

This mechanism can be illustrated by observing the surface of a steel plate (Fig. 1A) submerged in a quiescent distilled water solution containing sodium chloride and a modified "ferroxyl indicator" solution. The "ferroxyl indicator" solution consists of potassium ferricyanide and phenolphthalein.

The *anodic* process is shown by the formation of a blue floc (Prussian blue) resulting from the reaction of the ferrous ion and the potassium ferricyanide. This blue floc is essentially the corrosion product (rust) forming when the pitting action is taking place. The amount of tuberculation or rust, which is much more voluminous than the metal from which it was formed, is equivalent to the iron atoms which have left the metal structure and entered the corroding media in the form of ferrous iron (Fe^{++}).

The *cathodic* processes occurring over most of the metal surface are shown by the development of red color with the phenolphthalein indicator. No blue floc is found on these areas, indicating that there is no loss of metal at such points.

Thus the freely corroding metal surface in contact with the corroding media may be pictured as consisting of many irregular shaped and spottily distributed areas at which metal wastage is occurring, while the remainder of the surface is free of attack. The flow of current from the local anodic areas through the corroding media is essentially supplying a degree of natural cathodic protection to the rest of the exposed surface. The magnitude of the corrosion current and in turn an equivalent amount of metal wastage at the local anodic areas, is governed by the rate of depolarization occurring on the cathodic surfaces.

Unfortunately in the case of iron and most other metals, there are processes and acceptors (depolarizers) for the electrons released by the anodic process which do not permit the more cathodic areas to polarize to the open circuit potential of the anodic areas. Hadley[8] has enumerated five cathodic processes which may govern the rate of electrochemical corrosion. The first three are well known and may be observed to varying degrees in natural waters.

1. Combination with dissolved oxygen.

$$[H\text{-}OH + \tfrac{1}{2}O_2 + 2e \rightarrow 2OH^-]$$

2. Depolarization by agitation or bubbling off of hydrogen.

$$[2H^+ + 2e \rightarrow 2H^\circ \rightarrow H_2]$$

3. Direct chemical combination with the electrolyte or salts, for example the reduction of ferric ions to ferrous ions.

$$[2Fe^{+++} + 2e \rightarrow 2Fe^{++}]$$

4. By entering into the metabolic processes of certain anaerobic bacteria.

5. Combination with the products of microbiological metabolic processes.

The last two methods mainly occur in airfree soils and waters. Fig. 3 was developed by Wilson[1] in 1923 to indicate the relative influence on the corrosion rate of iron by the pH and dissolved oxygen concentration of the water.

From this it is evident that the corrosion rate in natural waters is governed mainly by the dissolved oxygen depolarization process, although it is known that the hydrogen evolution process occurs simultaneously.

For all practical purposes the rate of corrosion represented by hydrogen evolution is not significant in the absence of dissolved oxygen until the pH is less than 5.0 at normal temperatures.

When the acidity of the electrolyte drops below pH 5.0, the hydrogen ion pressure is sufficient to overcome the hydrogen overvoltage at the metal surface and cause marked evolution of hydrogen gas. This is the acid type of attack.

To further illustrate the key part that dissolved oxygen (O_2) plays in the rate of corrosion in neutral waters,[10] it has been noted that with all other conditions equal the corrosion rate of iron increases linearly with the dissolved oxygen concentration up to 5.5 cc. per liter.

Current Density Requirements

Although an excessive current density will not prove to be harmful to iron as it does to the more amphoteric metals such as aluminum,[11] the cost of the original installation and of operation dictate that the minimum current density requirements be established for complete protection against the corrosion environment being encountered.

Current density requirements for any corrosion problem have been generally chosen on a "rule of thumb" basis, which the worker may feel is adequate for a specific type of problem. Davy[3] indirectly established the minimum current density requirements for the protection of copper against sea water by observing that the ratio of copper to zinc must be less than 150 to 1 to obtain complete protection.

An examination of the literature on cathodic protection indicated current density requirements ranging from 0.3 to 60 mille amperes per sq. ft. for the protection of iron against various water solutions. Generally very little thought has been given to the factors which may cause this wide variation in current density requirements.

Clement and Walter[12] in some of the first fundamental work done on cathodic protection established two conditions affecting the c.d. requirements for the protection of steel against O.01N H_2SO_4.

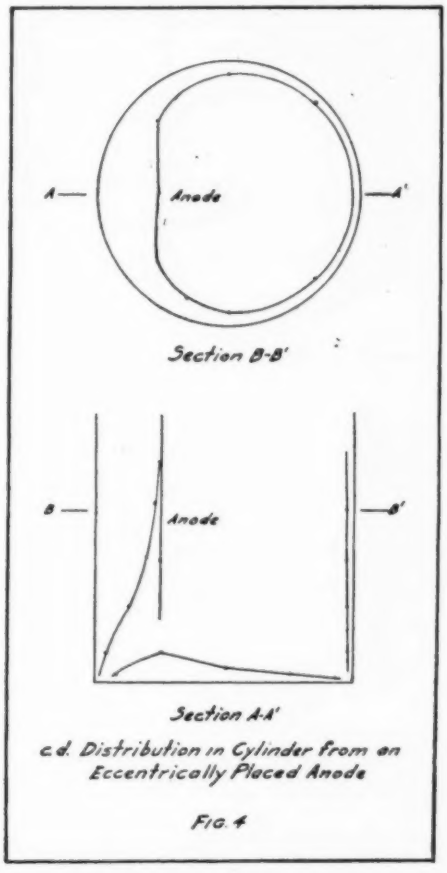


Fig. 4—Results of a Current Density Distribution Study Revealing Facts Contrary to Expectancy.

First, they observed that the current density requirements increase with increasing dissolved oxygen concentration.

Secondly, with all other conditions being equal, increasing the stirring increases the current density requirements.

These observations may be visualized more readily if we consider the presence of a stagnant layer of solution existing at the metal surface. This stagnant layer (Fig. 1A and B) acts as a barrier to the diffusion of dissolved oxygen from the bulk of the water to the metal surface. If we increase the dissolved oxygen concentration in the water we increase the number of oxygen molecules reaching the metal surface. By increasing the temperature or the velocity of the corroding media next to the metal surface we reduce the effective thickness of the diffusion layer and increase the rate of oxygen diffusion.

Since the rate at which dissolved oxygen reaches the cathodic areas through the diffusion layer governs the rate of metal wastage in natural waters, we can see that the superimposed current from an auxiliary anode (Fig. 1B) required to retard the rate of corrosion at the natural anodes will also be influenced by the dissolved oxygen concentration and the factors controlling the effective thickness of the diffusion layer.

Work done by the writer has indicated that in quasi-stagnant corrosion media of water containing less than 1.0 ppm. of dissolved solids, 0.1 N and 1 N NaCl solutions, with controlled oxygen concentration in the bulk of the media, the current density requirements for complete protection vary directly with the dissolved oxygen concentration and is relatively independent of the salt concentration.

The Effects of Calcium and Magnesium Salts

The degree of lime saturation of the natural water markedly affects the current density requirements for metal protection. A high degree of lime saturation in a water, as shown by the Langelier Saturation Index, inhibits the corrosion process. This is true because the smallest natural corrosion current develops sufficient alkalinity on the cathodic areas to precipitate a deposit of $CaCO_3$ from this water, increasing the effective thickness of the diffusion barrier and in turn reducing the amount of oxygen reaching the cathodically active points on the submerged metal surface. However, the saturation of a water with calcium carbonate and a pH of 10.3, such as that found in the water in contact with the freely corroding specimen (Fig. 2) should not be relied upon alone to completely stifle the corrosion process in the presence of appreciable amounts of dissolved oxygen.

The ordered reduction of the hydrogen ions and the migration of the cations such as Ca^{++}, Mg^{++} and Na^{+} to the protected cathode surface when projected current is applied, produces a highly alkaline film at the metal surface which is indicated by the red color developing when the "ferroxyl indicator" is used (Fig. 1B). The calcium bicarbonate $Ca(HCO_3)_2$ and/or magnesium ions in the bulk of the water coming in contact with the highly alkaline solution developed at the boundary of the diffusion layer precipitates calcium carbonate ($CaCO_3$) and/or Mg $(OH)_2$ at the metal surface. This often appears as a chalky coating on a protected metal surface. [Note uncleaned protected specimen, Fig. 2.]

Even waters with very little $Ca(HCO_3)_2$ and magnesium ion will deposit a $CaCo_3$ and/or $Mg.(OH)_2$ film providing the current density being applied produces a sufficiently high alkalinity at the metal surface.

From the foregoing it should not be assumed that cathodic protection is *entirely* dependent on the presence of calcium and magnesium salts in the water for effectiveness. The writer has protected steel surfaces immersed in aerated water containing less than 1.0 ppm. of dissolved solids. Clement and Walker[12] and U. R. Evans[13] have protected steel cathodically against dilute acid solutions. The advantage of calcium and magnesium salts in water is that the current density requirements for complete protection are lower in their presence and consequently make for greater economy of process.

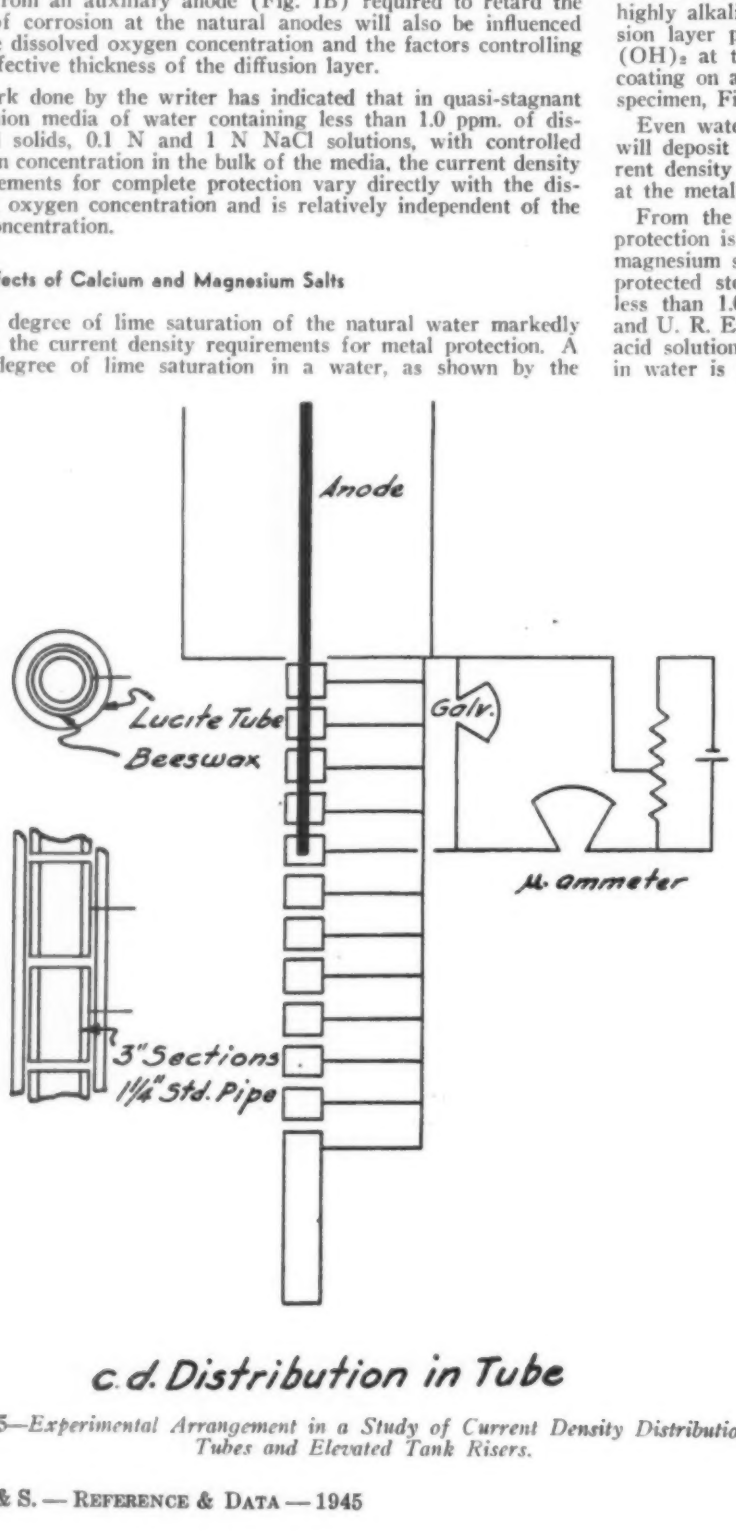


Fig. 5—Experimental Arrangement in a Study of Current Density Distribution in Tubes and Elevated Tank Risers.

The Effect of Protective Coatings

Paint and asphaltic coatings, even though they may be in a very poor condition, will reduce current density requirements since they are effective diffusion barriers and by the electrical resistance of their films concentrate the flow of current to points of film failure where the metal is exposed. Experience in the application of cathodic protection to underground pipelines has shown that the condition of the protective coating markedly influences the current density requirements.

Since the natural corrosion current is governed by the depolarization rates occurring on the more cathodic areas of the steel, the projection of an applied current from a submerged auxiliary anode to the metal surface will reduce the current leaving the local anodic areas on the steel. Increasing the applied current reduces the local current flow until the "protective current density" is reached, at which point all local corrosion currents have been stifled. It has been observed in 1N salt solutions that the potential of the steel does not change until the "protective current density" is reached, since the freely corroding steel surface potential is governed by that of the cathodic areas and the actual current density flowing to the cathodic areas has not been altered up to this point. Instead of supplying the current from the local anodes on the metal surface it is now supplied from the auxiliary anode in the corroding media (Fig. 1B). Above the "protective current density" the potential[14] of the specimen behaves similarly to a hydrogen electrode. Ewing has shown that a measurement of the metal potential alone is not a criteria of protection.

M. DeKay Thompson[9] has observed that the degree of protection of steel surfaces in NaCl and Na_2SO_4 solutions by an applied current is directly proportional to the cur-

rent density applied up to the "protective current density." This suggests that the use of insufficient amounts of applied current for *complete* protection are still of benefit since it will tend to reduce the local corrosion currents in any event. He also observed that in the same environment the current densities required to protect cast iron as against steels did not differ markedly.

It should not be assumed from the foregoing that the required current density for protection is just equivalent to the natural corrosion current represented by the metal wastage. There are many factors which do not permit this assumption to be valid. One of these may be visualized if we consider the cathodic areas in natural corrosion to represent only a portion of the exposed surface. When an applied current is used some of it flows to the areas which were anodes in normal corrosion. Often it is the case that many times the natural corrosion current must be applied from the auxiliary anodes to completely stifle the corrosion process.

Anode Design

The criteria of good anode design is the proper distribution of the current density, long anode life and the establishment of a low resistance through the corroding media between the anode configuration and the surfaces to be protected. It may be thought that the centering of an anode in a water tank with a flat bottom would provide a uniform current density to all surfaces which are equidistant from the anode. In the slightly more complex case of an eccentrically placed anode in a steel cylinder with a conducting floor (see Fig. 4) the current density distribution determined experimentally by the writer does not substantiate this thought. [The current density distribution was obtained by a probe technique developed by the writer.* Also, this probe technique has been employed to study the current distribution over the surfaces of complex structures from an operating cathodic protection installation, such as a Dorr clarifier mechanism.]

In order to picture the distribution of current in condenser and boiler tubes, pipes or in elevated tank risers, a test assembly (Fig. 5) was constructed of sections of pipe insulated from one another. Conductors led from each section were grounded to the tank which represented the water box of a condenser, drum of a boiler or bowl of an elevated tank. The current density on any section could be determined by dividing the current measured flowing to the section in question, by the surface area of the section. Table I illustrates the current density flowing to each section from a centered 3/16-in. diameter electrode extending to the bottom of the fifth section using a 5 per cent NaCl as the electrolyte. (See Fig. 5.)

TABLE I

Section	Current Density (Average)
1	4.3 micro amps/sq. cm.
2	4.0 "
3	4.5 "
4	4.0 "
5*	4.0 "
6	0.5 "
7	0.2 "
8	0.0 "

*Anode terminated in Section 5.

These data indicate that the current distribution extends only a short distance from the end of an electrode within a cylinder. From this it may be concluded that the anode design should be made to properly distribute current without any reliance on the so-called "throwing power" of the current input.

The ideal anode material would be one which resists deterioration when current flows from its surface, is inexpensive, does not introduce deleterious products into the electrolyte, is mechanically strong, has a low resistance and may be fabricated in sizes and shapes required to conform to the conditions encountered. There is no perfect anode material for all problems and the conditions found in the application will dictate the material used. Amongst the materials generally considered are carbon, graphite, mild steel, chrome and stainless steels, duriron, aluminum, zincs, copper, platinum, gold, etc.

The theoretical volumes and weights which will be lost by metals per ampere year of current flow are revealed in Table II. In the case of graphite the mechanical loss due to sloughing off of the particles of graphite are often much greater than the electro-chemical values would indicate.

TABLE II

Electrochemical Equivalents of Anodes

Anode	Sp. Grav.	Lbs./Amp. Yr.	Cu. in./Amp. Yr.
Iron	7.86	20.1	71.0
Graphite	2.26	2.3	37.0
Zinc	7.14	23.5	91.4
Nickel	8.90	21.3	66.5
Aluminum	2.702	6.4	65.7

*Reported on in a paper presented by the author to the Fifth Annual Water Conf. of the Engineers' Soc. of Western Pennsylvania, October, 1944.—Ed.

Water Quality and Current Density

A paradox found in the application of cathodic protection is the observation that for waters of high resistance (low solids content), higher current densities are usually required than for waters of low resistance. The implication of this thought may be gathered when we compare midwestern waters with a specific resistance of 1200 ohms per cm. cubed with that found along the eastern seaboard, whose specific resistance is often 20 times as great. For the same tank and electrode arrangement, 20 times the power consumption would be required to supply the same current to the eastern tank. A reduction in power consumption can be accomplished only by altering the "cell constant" of the electrode-tank configuration. This can be done by increasing the number and altering the spacing of the electrodes and/or increasing the ratio of the anode diameter to the tank diameter. For an anode centered in a cylinder,[15] the effect of the ratio of the anode to tank diameters upon the resistance may be predicted from the following relationship:

$$\text{Resist.} = \frac{2.303}{2\pi} r \log_{10} \left[\frac{R_2}{R_1}\right]$$

where

r sp. resistance
R_1 Anode diameter
R_2 Cylinder diameter

Part II—Comments on the Practical Application of the Process

IN ORDER to mitigate the corrosion process of steel surfaces in contact with natural waters by cathodic protection, it has been shown in Part I that for each corrosion environment a certain "minimum current density" must be projected from an auxiliary anode configuration through the water to the surface to be protected. The "minimum current density" required to stifle the local corrosion currents on steel surfaces in a natural water environment is largely governed by the coloumb-second or ampere-hour effect occurring in the electrochemical reduction (a) of the dissolved oxygen reaching a unit area of the metal surface through the diffusion layer existing between the metal surface and the bulk of the water.

$$\text{(a)}\quad HOH + \tfrac{1}{2}O_2 + 2e \rightarrow 2OH^-$$

From these principles previously discussed it becomes apparent that the effectiveness of cathodic protection is independent of the source of the projected current so long as the amount is adequate.

Sources of Protective Current

The flow of protective current may be motivated in one of two manners:

(1) Using a metal plate whose solution potential in the particular corrosion environment is greater (more anodic) than that of the metal to be protected, a protective current can be produced. The potential difference between the two metals in the corroding media results in the flow of current from the more anodic or sacrificial metal through the solution to the metal surface being protected, if an electric circuit is provided between the metal being protected and the anode. An example of this method of corrosion control, which may be better described by the term "galvanic protection" rather than "cathodic protection" is the use of zinc plates coupled to steel surfaces. Metals such as cadmium, aluminum, and magnesium have also been found to have a protective effect when coupled with iron. Another example whereby the potential difference between two metals may be used to protect the less anodic metal was illustrated by Davy[17] when he used iron, which in most environments is anodic to copper, as a sacrificial anode to protect the copper sheathing of ships in sea water. [We are all familiar with the phenomenon occurring when iron is coupled with copper in aerated waters. The iron immediately adjacent to the copper is usually severely attacked, with the degree of attack on the iron diminishing as the distance from the copper is increased.]

There are two main limitations in the use of zinc plates or some of the other more anodic metals for providing the necessary "protective current density" on steel surfaces. Reviewing the electrochemical equivalents of metals in the first article of this series, it was shown that at least 23.5 pounds of relatively expensive zinc would be consumed per ampere year if there were no other anodic processes occurring. This zinc consumption, resulting from a current flow of one ampere for one year to the steel surface, does not include the zinc loss occurring because of the local corrosion currents flowing over the zinc surface. In

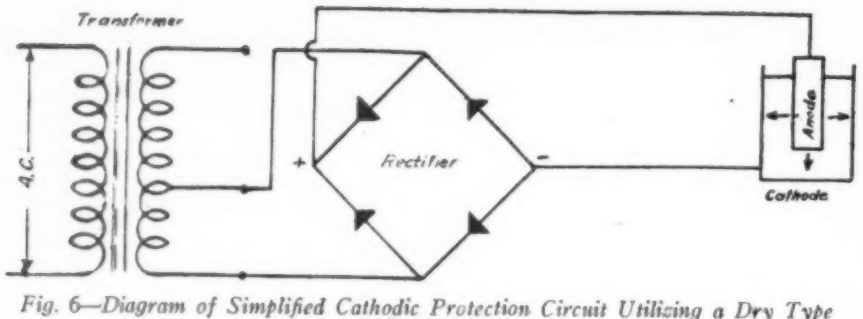


Fig. 6—Diagram of Simplified Cathodic Protection Circuit Utilizing a Dry Type Rectifier.

most cases experience has shown that the cost of zinc plates, which serve both as an anode and a potential force, is prohibitive.

The shortcoming of this galvanic method is that the potential difference existing between the more anodic or sacrificial metal and the metal to be protected usually is not sufficient to overcome the resistance through the corroding media and supply an adequate current density to completely stifle the corrosion currents over large areas. It has already been stated that the application of a current density below the "minimum protective current density" will give only partial protection. Because of the limited potential driving force available, complete protection usually extends only a few inches away from the zinc plates. Beyond the outer edge of the area, where complete protection is observed, the protective effect diminishes as the distance from the zinc increases because of the gradual decrease of the current density flowing to the surface of the metal being protected.

(2) The second and most used method of projecting current flow from a properly designed auxiliary electrode configuration in the corroding media to the surfaces to be protected is with an external potential force which can be regulated to drive the current required for protection.

The external potential force to be applied to the auxiliary anodes in the form of direct current can be developed by storage batteries, wet type rectifiers, dry type rectifiers, motor-generator sets, gas-engine generators and windmill generators.

Because of the conditions met in the practical application of cathodic protection, the equipment selected for this purpose should have the following characteristics: low initial cost, require very little maintenance, have a high efficiency in the conversion of energy to the proper direct current, be easily adjustable to meet potential and current requirements of the corrosion control installation, be unaffected by weather and climate, attractive in appearance, operate continuously, etc.

Rectifiers

The equipment most frequently selected for developing the external potential force for driving the current in the application of cathodic protection to pipelines and submerged steel structures is the dry type rectifier. There are three well developed dry type rectifiers commercially available at the present time. These are generally referred to as copper oxide, selenium, and copper sulphide rectifiers. These rectifiers are dependent upon the electrical check-valve properties of certain metals for converting alternating current to direct current. It has been found that the formation of copper oxide on one side of a copper disc of high purity, by controlled exposure to heat and air, creates a unique electrical check-valve property. By making an electrical contact to the metallic copper, and another through lead discs in contact with the copper oxide formed on the surface of the copper, it is observed that unidirectional current will encounter less resistance and flow more readily from the copper oxide film to the copper than in the reverse direction; i.e., from copper to copper oxide. Basically, the selenium and copper sulphide rectifiers function on the same principle as the copper oxide rectifier does. By using this check-valve property, rectifier stacks can be assembled for converting alternating current to unidirectional or direct current, using the full wave of the a-c cycle. Fig. 6 is a simple diagram to show the position of the rectifier stack in the electrical system used in converting A.C. to D.C. for cathodic protection.

A transformer having variable taps on the secondary winding is used to supply alternating current at the proper voltage for rectification. The a-c voltage applied to the rectifier stack is governed by the resistance to be overcome in the rectifier circuit and, more importantly, between the anodes and the surface being protected; so that an adequate current density is provided to stifle the corrosion currents on the steel in the particular environment being encountered.

Copper oxide rectifier stacks, which have been in continuous operation for more than fifteen years, are reported by the manufacturer to be functioning satisfactorily with very little drop in efficiency from that originally observed. The copper oxide and the selenium type rectifiers are somewhat more efficient in current conversion than are the copper sulphide rectifiers. Their overall efficiency, including the transformer when operating at rated capacity on full wave single-phase rectification, is in the neighborhood of 55 to 65 per cent, depending on the particular characteristics of the rectifying unit assembly.

Over two thousand copper oxide rectifiers, some of which were installed more than six years ago, have been functioning continuously in normal operation with no breakdown of the rectifier stacks. Fig. 7 illustrates a typical rectifier assembly in a weatherproof housing, used in the application of cathodic protection to steel water tanks. Usually these rectifiers are cooled by natural convection of air over their cooling fins, although fans are sometimes used on larger capacity units to reduce the size and cost of the rectifiers.

Fig. 7—Copper Oxide Rectifier Used in Cathodic Protection of Water Tanks and Sewage Plant Equipment.

Motor Generators

Motor generators[18] are frequently used in converting A.C. to D.C. of the proper characteristics for cathodic protection. They are most practical when the output requirements exceed 3,000 watts. Because of moving parts, motor-generator sets require considerable maintenance attention and necessitate proper housing for protection from the elements. Motor generators are usually more efficient than the dry type rectifiers, but their original cost is greater than that of a dry type rectifier of equal capacity.

Windmill and Engine Generators

Windmill generators are sometimes used in pipeline protection where A.C. is not available. They are dependent on continuous wind velocities in excess of 5 mph. An electrical circuit has been designed[19] whereby storage batteries charged by a

windmill generator may be used to provide current during periods of low or no-wind velocity.

Gas engine generators,[15] taking gas as a fuel from the pipeline being protected, are being used on natural gas pipelines in regions where the wind velocity or constancy is not adequate for windmill generators and A.C. is not available for rectifiers. At sewage plants engine generators may well be considered because of the availability of by-product fuel in ample quantity.

Storage batteries, except as a supplement to windmill generators, or the wet type rectifier, are rarely used in cathodic protection practice because of their low efficiencies and high maintenance costs.

Evaluating Protection

Evaluating the degree of protection being derived from any one of the four basic methods of corrosion control, including cathodic protection, is often complex, and such an evaluation should be made by a highly competent engineer experienced in corrosion.

One can be guided by the principles of the electrochemical corrosion mechanism for evaluating the effectiveness of cathodic protection, which was discussed in Part I. There are two phenomena which in practice characterize the corrosion of steel in natural waters; namely, the wastage of metal usually evidenced in the form of pits and the coincidental formation of rust or tubercles.

It was noted that, in the corrosion process, iron atoms leave the crystal lattice of the metal surface and enter the natural water or other corroding media as ferrous ions. This process is physically shown by the development of pits on the localized anodic areas. The pitting type of attack is unfortunate, since many structures can no longer confine liquids when leaks develop even though more than 99 per cent of the original metal in the structure is sound and intact. On this ground, it becomes evident that the rate of attack or pitting of steel in localized areas is often more important than the total amount of metal lost.

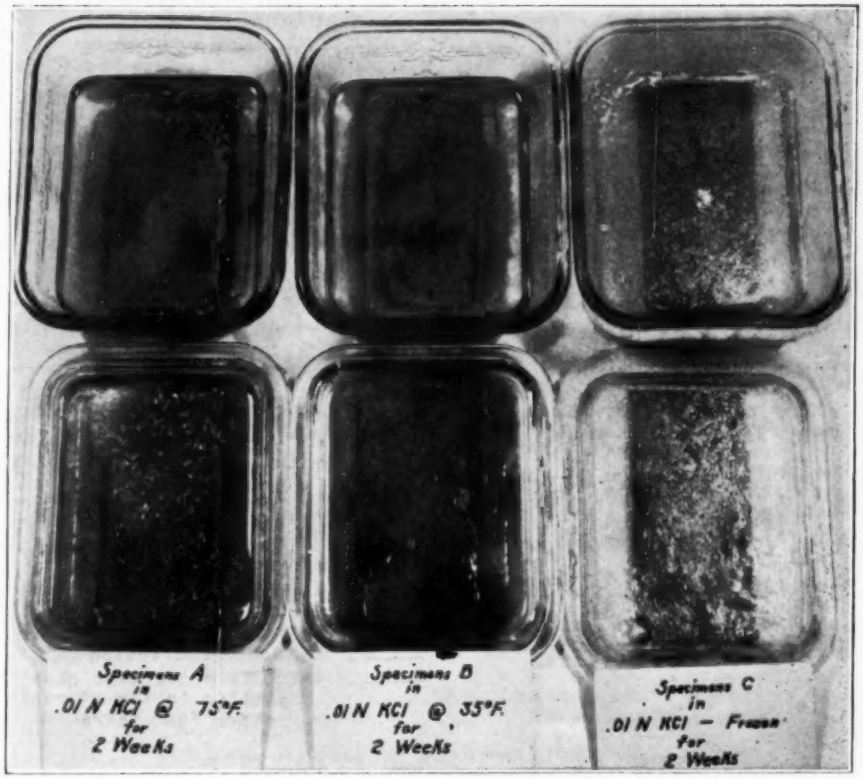


Fig. 8—Test Specimens Used to Study the Rates of Corrosion of Steel at Low Temperatures and the Effect of Ice Coating in Excluding Oxygen and Elimination of Corrosion Behind Ice Formations in Elevated Tanks or Standpipes.

Rust and tubercles, the corrosion products familiar to everyone, are formed by the precipitation and oxidation of the ferrous ion introduced into the corroding media by the natural anodic processes occurring on the steel surface. This rust usually covers the pitted areas and is observed in many forms. In cases where the corrosion process is active, and is under oxygen control, a hydrated black ferri-ferrous oxide (magnetic in nature) is found in the bottom of the pits. As the outer surface of the corrosion nodule is reached, the dissolved oxygen in the water has converted the black magnetic iron oxide to the more highly oxidized form of iron, and is commonly seen as red rust or hydrated ferric oxide.

The volume of rust created by the corrosion process which covers the pitted areas cannot be used as a basis for estimating the depth and amount of pitting, because the volume of the corrosion product (in situ), is usually many times as great as that of the metal from which it was formed. The volume of the corrosion product is governed by the manner and the environment in which it was formed.

In general, the effectiveness of any method of corrosion control can be established by comparing the rate of metal wastage, indicated by metal thickness measurements or by weight loss over a definite period of time, when the corrosion control system is being used against the rate of metal wastage in the absence of the particular corrosion control method.

Determining the Effectiveness of Cathodic Protection

Great care should be taken in the use of corrosion test specimens and interpretation of results therefrom, for evaluating the degree of protection being obtained. Unless the specimen is of the same metal, and has the identical surface condition found on the structure being protected, the same current density will not produce an identical protective effect on both surfaces. Secondary corrosion currents, resulting from the dissimilarity of the test specimen and the surface of the structure being protected, will lead to erroneous results often unfavorable to the method of corrosion control being applied.

Another condition to be met in the proper use of test specimens is that the specimens should receive the same current density as the wall being protected. This may be accomplished by coating one side of the specimen with wax and placing the waxed surface face against the wall. The author, in using this technique for current density distribution studies, found that the test specimen would receive within ten per cent the current density reaching an equal wall area having an approximately identical surface condition providing the potential drop through the current measuring device was compensated for by an opposing potential. Test specimens are usually compared with unprotected specimens in the same environment on the weight loss basis, since the depth of pitting characteristics on test specimens (sometimes called coupons) are rarely comparable to those found on the submerged structure. Test specimens, positioned some distance from the wall of the structure, will usually receive a higher current density than an equal area on the wall. This is true particularly in water tanks. Although test specimens have many limitations, they are helpful in establishing a general picture of a particular corrosion phenomenon.

Measuring the depth of pits at intervals by means of a depth gage resting on corrosion-resistant permanently fixed pins, is one of the most satisfactory methods of establishing the degree of protection obtained, providing the cathodic film around the pit is not disturbed. By disturbing the cathodic layer of calcium carbonate, rust, etc., around the pits, a higher current density will be required to stifle further progress of the corrosion process. Therefore, if a corroded tank is cleaned a larger current input will be required in the early stages to stop the corrosion which would otherwise be accelerated.

Complete protection of a new uncorroded surface is established, if pitting or the accompanying formation of rust is not observed.

The formation of a white deposit consisting mainly of calcium carbonate on the metal surface by the application of cathodic protection is usually clear-cut evidence that the corrosion process has been stifled. The loosening of previously adherent rust and tubercules by the formation of alkali and/or the evolution of hydrogen gas between the rust and metal surface, when a current density greater than that required to reduce the dissolved oxygen

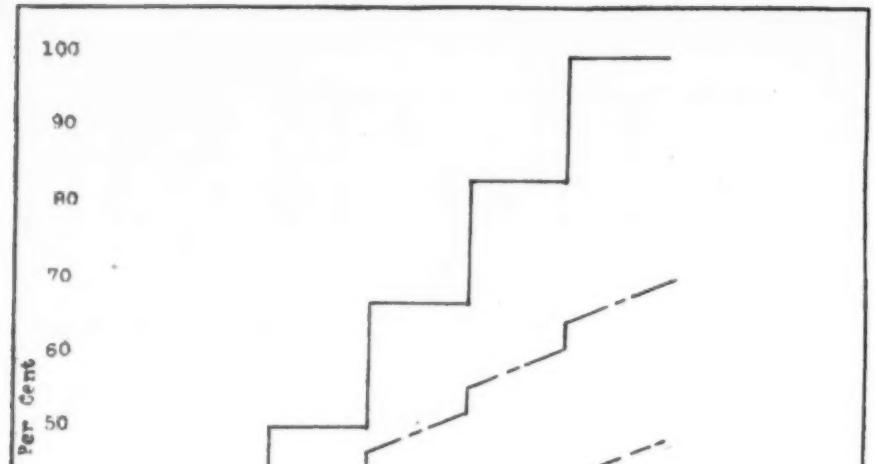


Fig. 9—A Comparison of Overall Costs of Cathodic Protection vs. Painting of Interior Tank Surfaces During a 24-Year Period.

reaching the metal surface is applied, also indicates protection. Often this old corrosion product will be loosened and then slough off the metal surface by its own weight. In the author's opinion, however, this rust layer, if it is continuous over the metal surface, is an effective cathodic layer and will decrease the current density requirements for complete protection. It is therefore a waste of effort and money to clean the walls of corroded tanks, etc., before applying cathodic protection.

"Null"[21] and other electrical methods[14] have been developed whereby changes in metal potential, measured against a standard reference cell with varying projected current densities, may be interpreted to indicate the "minimum current density" requirements for complete protection. Although these techniques are intricate, in recent years they have been widely used in evaluating current requirements for pipe-line protection.

Ewing[14] has found that applying a current density sufficiently great so that an arbitrarily selected potential on a metal surface in respect to a reference electrode is reached, is not always a criterion of complete protection.

Cathodic protection cannot be expected to replace metal already lost by the pitting action or to cause rust formed before the application of cathodic protection to vanish. The main purpose of this method of corrosion control is to retard the rate of attack so that the useful life of the structure being protected will be extended beyond that which can be realized by other means of corrosion control. The reading of an ammeter on a rectifier should not be used as a criterion of protection.

In the protection of petroleum and natural gas pipelines, which have been installed for some time prior to the application of cathodic protection, a comparison of the leaks found each year before treatment against the number occurring after cathodic protection is applied has provided a very satisfactory way in establishing the value of cathodic protection.

Water Tanks

In tentative specifications on the maintenance of elevated steel tanks and other water storage tanks, prepared by a committee of the A.W.W.A. in 1943, it is stated: "Experience has shown that in practically all cases the inside surfaces of a water storage tank are in worse condition than the outside. Almost without exception tank bottoms which have had to be replaced on account of leaks through the steel have corroded through from the inside." From these statements it is apparent that the inner submerged surfaces will demand greater attention insofar as corrosion control is concerned than the outside. It has been the author's experience in examining many tanks that the bowls of elevated tanks and the floors of standpipes are usually attacked much more severely than the vertical walls are. This may be accounted for by the localization of attack on areas under insoluble suspended matter which has settled on the horizontal or inclined surfaces of the tank. For example a leaf covering an area on the floor will cause pitting underneath it, since the leaf masks this area from the dissolved oxygen in the water. The areas around the leaf will be more accessible to the dissolved oxygen in the water and will become the cathode of the oxygen differential concentration corrosion cell, where the depolarizing process controlling the rate of corrosion will take place. Unrelieved stresses resulting from the fabrication of the floor plates may also cause corrosion cells.

For more than eight years cathodic protection has been extensively applied in the mitigation of corrosion of tank surfaces in contact with corrosive waters. Experience and considerable fundamental research conducted during this period has shown that the mere installation of an anode from which current flows according to an arbitrarily chosen fixed current density constant usually will not provide satisfactory protection. In each tank the corrosion problem is unique and the engineering design of a proper cathodic system demands an accurate interpretation of the the corrosion environment. Some of the fundamental factors influencing current density requirements and anode design are discussed in the first article of this series—see Part I.

Some Case Histories

A practical example of the effectiveness of cathodic protection is illustrated by an installation in a 100,000-gallon elevated tank with an ellipsoidal bottom in Dayton, Ohio, which was built in 1931. The tank was initially painted with one shop coat of red lead and then covered with a field coat of red lead after erection. The tank water level was automatically maintained with a fluctuation of about two feet between high and low water. In 1939 several leaks developed in the bowl of the tank resulting in the need for immediate repair. The leaks and most of the pit depressions were repaired by welding. The AWWA specifications[23] previously mentioned state that "such a leak indicates that the entire bottom may be thin and other leaks may soon appear. The use of welding to patch such leaks is of very doubtful economy as the heat of welding very often is the cause of new leaks. Even if a considerable area is welded, it may be but a short time after such repairs are made before new leaks appear."

After repairing the tank bowl in 1939 a cathodic protection system was designed and installed in this tank. An examination of the tank bowl, vertical walls and riser, in the summer of 1944, showed these surfaces to be in very good condition and that the tank should serve without further repair for many years. This particular corrosion problem was extremely interesting since the water confined was from a deep well source containing very little dissolved oxygen and apparently having salts in amounts characteristic of the deep well waters in this midwestern area. However, the dissolved oxygen concentration in the bowl of the tank increased because of contact with the air surface, as will be noted in the analysis below:

Deep Well Water "A"

$Si-O_2$	21	ppm.
Ca (Calcium)	93	ppm.
Mg (Magnesium)	31	ppm.
Na (Sodium)	9	ppm.
Bicarbonate alk.	337	ppm.
SO_4 (Sulphate)	72	ppm.
Cl (Chloride)	20	ppm.
Total Hardness as $CaCO_3$	360	ppm.
pH	7.3	ppm.
Dissolved O_2 in well water	.28	cc./liter
Dissolved O_2 in water in bowl of tank	3.6	cc./liter

A relatively low current density in this case proved to be adequate in retarding the progress of further corrosion and to form a white deposit on the submerged metal surface through the interaction of the $Ca(HCO_3)_2$ in the bulk of the water with the highly alkaline layer on the metal surface produced by the ordered reduction of the hydrogen ions and the dissolved oxygen reaching the metal surface by the protective current flow. Because of the absence of appreciable amounts of incrusting salts in some waters, a higher current density would be required than was applied in the previously described case.

The dissolved oxygen concentration usually is not uniform throughout a tank. Studies made by the author on many tanks have generally indicated that with water supplied containing a low dissolved oxygen concentration, the concentration of dissolved oxygen in the tank will decrease with the depth from the surface, whereas in tanks supplied with water having a high dissolved oxygen concentration, the oxygen concentration will increase with the depth from the surface. This variation in oxygen concentration may affect the intensity of corrosion in the tank at different depths and will affect the current density requirements for complete corrosion control on these areas.

There are three factors which govern the dissolved oxygen content in the water throughout the tank and probably account for the above observations.

1. Oxygen from the air will tend to enter the water through the water surface-air interface.[23] The amount of oxygen dissolved will be governed by surface area, temperature, movement of the bulk of the water, the oxygen already in the water, etc.

2. Oxygen already in the water will be consumed by the corrosion current or if cathodic protection is applied by the projected current, i.e., reduction of the O_2 reaching the metal surface to hydroxyl ions according to the reaction shown early in this article. Aerobic micro-organisms in the water will tend to consume dissolved oxygen. This behavior of the micro-organisms has been demonstrated by the absence of dissolved oxygen in sea water[24] at great depths and in the far ends of water distribution mains.

3. The other factor governing the variation of the dissolved oxygen concentration throughout the tank is the displacement phenomenon which occurs when water enters or leaves a tank. On a humid summer morning one will note, as water is being pumped into the tank, the formation of a distinct boundary ring below which condensation occurs. This ring creeps up the tank wall as the tank is being filled, indicating a distinct line of demarcation between the bulk of the water already in the tank and the cooler incoming water. The author has observed this phenomenon on the risers of elevated tanks and on the walls of standpipes whose diameters have often exceeded 100 feet.

In some cases where the incoming water is very corrosive because of a high oxygen concentration, anodes should be provided in elevated tanks to protect the riser. The author in Part I has shown data indicating that only a very small current density would reach the riser walls from anodes suspended in the bowl of the tank. An anode extending the full length of the riser is often required to satisfactorily protect the riser.

A great deal of emphasis is usually placed upon the corrosion occurring on the intermittently submerged surfaces of a tank. Studies made by the author on a midwestern elevated tank indicate that cathodic protection will cause deposition of $CaCO_3$ and/or $Mg(OH)_2$ on these surfaces during submergence and that this deposit will effectively protect the surface during the period of atmospheric exposure.[25] In waters from which it is difficult to deposit protective scale-forming salts, protection will be obtained only when the surface is submerged and an adequate current density reaches the area. On re-exposure to the air in the absence of an insoluble salt coating corrosion can proceed. However, the corrosion rate during the period of exposure to air is usually negligible compared to that which would occur if the area is submerged in the absence of cathodic protection. In practice it is recommended that the inside of the roof and the wall of the tank be painted down to the mean water level when cathodic protection is applied. The author has already stated that attack on the floor of a tank is usually more severe than that found on the intermittently exposed surfaces of the tank. Therefore, any effective cathodic system must be designed and operated so as to insure maximum protection for the tank bottom and riser pipe.

Ice Interference

In the engineering design of a cathodic protection system some consideration must be given to the formation of ice within water storage tanks and other submerged structures. Ice formation in water tanks is commonly found along the northern fringe of the United States and in Canada where the mean temperature is far below freezing for many months. This ice generally starts to form on the submerged walls of the tank and finally bridges across the surface of the water. Peak thicknesses of 7 to 8 ft. of ice along the tank wall have been reported in Montreal,[26] although thicknesses of 1 to 3 ft. are more common in the United States. The formation of ice in tanks is influenced by the mean temperature outside, frequently of water change in tank, temperature of water in supply system, heat dissipating surface area vs. tank volume relationship, tank covering, location insofar as wind protection, etc. A change in any one or all of the previously mentioned factors may account for formation of ice in one tank, whereas a short distance away in another tank little or no ice formation is encountered.

When the ice formation begins to melt, its behavior is not predictable. Often in breaking up, cakes of ice drop from the walls into the water, sink deeply and then float to the surface. In some cases the intact ice wall may ride up and down the inner tank wall like a piston with changes in temperature and of the water level. Cases have been reported where the upper edge of the ice cylinder will extend several feet above the rim of an open top tank. The movement of the ice tends to scrape the inner wall of the tank, scoring any protective coating. The scoring of a paint film will tend to hasten corrosion and require yearly patch paint application for satisfactory protection. This painting must be done as soon as the ice has melted since the most rapid corrosion on the exposed areas will usually occur during the summer.

Since it is common practice to suspend the anodes used in the application of cathodic protection to water tanks from supports above the surface of the water, it becomes evident that the shifting of ice in the tank may in some cases break or bend the anode assembly.

Much thought has been given to the most satisfactory procedure in applying cathodic protection where ice is prevalent.

Temperature and Corrosion Rates

A study of the influence of the formation of ice upon the corrosion rate of steel is most helpful in establishing the need for cathodic protection during the freezing period. In order to demonstrate this, the author placed two weighed hot rolled steel specimens 4-in. x 2-in. x 1/16-in. in a .01N KCl solution at 75° F., 35° F., and frozen in the solution respectively for two weeks. Fig. 8 reveals the results.

The .01N KCl (potassium chloride) solution used in this study being in contact with air, was extremely corrosive. The weight losses of the two specimens under each of the three conditions of temperature noted above are as follows:

Specimens	Original Wt., Grams	Final Wt., Grams	Weight Loss Grams	Temperature
A-12	60.1546	59.9557	0.1689	75° F.
A-13	60.1574	60.0009	0.1565	75° F.
B-14	60.6673	60.5576	0.1097	35° F.
B-15	60.5917	60.4836	0.1081	35° F.
C-16	60.3867	60.3865	0.0002	Frozen
C-17	60.1246	60.1240	0.0006	Frozen

The rust formed by the attack on specimens A and B may be noted by the presence of nodules of corrosion product along the edges of the specimens and the dark precipitate lying on the bottom of the glass vessels. The uneven surface of the ice accounts for the shadows showing on specimens C. Specimens C were quick frozen in the .01N KCl solution and no corrosion product was noted at the end of the two-week test period.

Even though the solubility of oxygen from the air was greater in the solution around specimens B at 35° F. than in the solution around specimens A at 75° F., the corrosion rate was greater on the latter specimens. This illustrates the influence of the temperature upon the effective thickness of the diffusion layer and the corrosion rate. Speller[11] has shown that the corrosion rate in an air saturated solution increases with temperatures up to about 80° C. Above this temperature the reduction of oxygen solubility in an open top vessel with increasing temperature becomes more apparent in its effect in the reduction of the corrosion rate, so that at the boiling point the corrosion rate is essentially zero.

The extremely high electrical resistance of ice, and its low fluidity which retards oxygen diffusion, results in a very low rate of corrosion attack of the steel coated with ice. From the demonstration it may be concluded that the progress of corrosion is negligible when the submerged surfaces of a steel structure are covered with ice.

In practice this is helpful since the anodes can be removed just before ice forms and reinstalled as soon as the ice melts to provide protection during the period that the metal is in contact with a corrosive water.

In order to eliminate anode removal and replacement each year, heated anodes are being considered along with anodes supported

from the floor of the tank below the ice. However, the use of these ideas is governed by peculiarities of the ice formation and operation of each tank.

Economic Considerations

The prime purpose of any method of corrosion control is to obtain the maximum useful life and the most satisfactory service from the structure being protected at the lowest overall cost. Failure to properly protect the submerged surfaces of a structure such as a water tank will in many cases result in a much greater depreciation rate of the tank than was anticipated at the time it was purchased. The financing and operating problems incurred by the need for early replacement or repair of the tank structure should be guarded against by a planned tank protection program.

The need for a planned corrosion control program applied to water storage tanks is illustrated by a statement found in an AWWA committee report.[29] "Such a leak may ordinarily exist only in the case of a very old tank or one which has not been cleaned or painted on the inside for about twenty years . . ." The author has previously discussed a tank which had leaks developing within eight years after erection. Other tanks, which are unprotected, depending upon the corrosion environment and operating conditions, may operate for more than twenty years without the development of leaks.

With a soundly planned corrosion control program, the life of a water storage tank should be extended to at least fifty years and even longer. Although there are always exceptions, it may be assumed generally that the depreciation rate of a water storage tank structure will be reduced from around five per cent a year to less than two per cent a year by the use of an adequate corrosion control program.

In comparing the cost of painting the inside of a tank against the cost of cathodic protection, certain basic principles should be borne in mind.

(1) Since a properly designed cathodic system will give complete protection of the submerged surfaces, its cost should be compared only against a painting cost in which the best type and grade of materials, labor and technique are used. This should include the proper cleaning of the surface by wire brushing, sand blasting or flaming before paint application; the best grade of red lead and cover coat paint; adequate drying time between the application of the first and second coats and the filling of the tank with water, and the proper application of the paint by a reliable painter. The protective value derived from a paint coating applied to an improperly cleaned and prepared surface or the use of substandard grade paint and labor will not justify the expenses incurred.

(2) If paint is used it is recommended that the tank interior be examined annually,[28] particularly where ice formation is found, and any areas where failures have occurred in the paint film should be patched. Finally, when the paint film has generally deteriorated the entire surface should be properly conditioned and repainted. Experience of the tank manufacturers[29] has shown that repainting is usually necessary every three to five years.

(3) Since the original cost of a cathodic protection system includes equipment such as a rectifier, wiring and other appurtenances whose estimated life is twenty-five years, any comparison of total cost of cathodic protection against painting should extend over this 25-year period. Experience during the past nine years has shown that the maintenance and operating costs of a cathodic protection system on water tanks, including anode replacements and labor and power, rarely exceeds eight per cent of the original cost annually.

Perryman[27] has prepared valuable data which establishes a basis for estimating the cost of protecting steel tanks by various methods. In estimating painting costs he has developed a chart showing the gallons of paint required to cover the inside and outside surfaces of tanks of various sizes and uses, and employs a factor of four times the cost of the paint to be added to that of the paint in order to cover the cost of labor, a nominal amount of wire bushing, scaffolding, etc. The cost of applying two coats of paint to the inside of the tank is about equal to the cost of a cathodic protection system. However, when cathodic protection is applied, the cost of painting the inside of the roof of the tank and the side wall down to the mean water level should be added to the cost of the cathodic protection system. In many cases the inside surfaces above the mean water level have been painted without emptying the tank.

Since the price structures change from time to time, the author has prepared Fig. 9 to illustrate the basic factors previously discussed which are involved in the comparison of the overall costs of protecting water tanks for a period of twenty-four years. The relative cost of painting every four years against the cost of cathodic protection is shown in terms of per cent, the cost of painting being 100 per cent.

Since cathodic protection can be installed and maintained in service without draining the tank, a condition which is necessary when paint is applied, the risk of being out of water in event of a fire or during peak load demand is eliminated. This advantage has not been evaluated but it can be visualized that under some circumstances the cost of a cathodic protection system can be paid for many times because the tank has remained in service during an emergency.

Another factor to be considered is that a paint film is not completely effective as a corrosion barrier during all the period between paintings. As time goes by, the paint film begins to fail so that at the end of three to five years a measurable amount of attack has occurred at the points where film has failed. On the other hand the effectiveness of cathodic protection is continuous so long as the equipment is properly maintained.

Part III—Applications to Hot-Water Tanks, Clarifier Mechanisms, and Deep Wells

Cathodic protection can be successfully applied to any steel structure submerged in natural water providing (a) the submerged surface contour of the structure lends itself to a practical anode design for proper current distribution and (b) an adequate current density is used to stifle the corrosion currents which flow through the corroding media between local areas of different potential on the surface of the unprotected metal. In addition to water storage tanks which are usually simple geometrical structures, cathodic protection is being used on other more complex structures in contact with natural waters. Amongst these are hot water tanks; clarifiers; deep well column pipe and well screens and casings; open tank condensers[30]; revolving screen frames; sludge blanket filtration and Zeolite type softeners; etc. The protection of pipelines in contact with corrosive soils by means of a current flow projected to the exposed metal surfaces is accepted practice by all the major oil and gas companies and some industrial and municipal water systems.[31, 44] The rate of depreciation of many miles of pipeline, originally well covered with coal tar enamel or asphalt coating, where, after a few years, the number of leaks per mile occurring yearly as a result of soil corrosion, often reached prodigious figures, has been reduced by the use of cathodic protection. A relatively small expenditure for a corrosion survey by an expert corrosion engineer, cathodic protection equipment and electrical energy, on a pipeline rendered nearly unserviceable because of soil corrosion, will reduce to reasonable limits the nuisance and loss from frequent leaks, and the need for ultimate relaying of all or a portion of the pipeline. The application of cathodic protection to sewage equipment is a relatively new field in which much work is under way as recorded by Parkes[32] and Kozma.[33]

The Hot Water Corrosion Problem and Cathodic Protection Experiences

Hot water tanks, such as those used in domestic, institutional and industrial water systems, provide an excellent illustration of some of the corrosion fundamentals that must be considered in cathodic protection design. Frequently the only serious corrosion problem encountered in a municipal water system is that found in domestic hot water tanks. It has been reported that over 500,000 domestic and commercial hot water tanks are replaced yearly in the U. S. because of corrosion. It can be seen that because of the magnitude of the problem those responsible for water systems are actively seeking methods for alleviating this corrosion. Many methods of corrosion control for hot water tanks have been tried and adopted. Amongst them are use of inhibitors; controlled lime saturation; deaeration; linings of cement mortar, glass, enamels or synthetic resin coatings; metallic coatings such as zinc, which often provide protection only for a limited period; and cathodic protection.

A general picture of the cause and characteristics of corrosion in hot water tanks using municipal water supplies may be obtained from a study of up-to-date power plant water conditioning practice. In order to prevent corrosion in a boiler feed water system, the water before passing through the piping and stage-heaters on its way to the boiler is usually deaerated in a mechanical degasifier where the water is exposed to favorable temperature and pressure conditions. Following this treatment sufficient sodium sulphite, or other oxygen scavenging chemical, is added to the water to reduce the traces of oxygen not removed by the deaerator. In spite of feedwater temperatures as high as 400° F., a pH as low as 6.5, the presence of dissimilar metals in heat exchangers, soluble salt concentrations ranging from 0.5-200 ppm. and the absence of scale-forming salts or inhibitors, the corrosion or pitting rate in feedwater piping, heat exchangers and tanks in the feed water system is negligible so long as *the dissolved oxygen is completely removed.* Since microorganisms

can hardly contribute to the corrosion process in hot water tanks, and since other oxidizing agents or depolarizers usually are not present in appreciable amounts in municipal water supplies, it becomes apparent that the factor governing this corrosion process is the presence of dissolved oxygen. At the present time it does not appear generally feasible to deaerate water distributed in municipal water systems because of the cost of deaeration, the possibility of encouraging the growth of anaerobic microorganisms and degradation of organic matter in the mains, and the presence of a flat taste found in the water when the soluble gases other than dissolved oxygen have been removed.

In a sense cathodic protection may be likened to an electrolytic deoxygenation process concentrated immediately on the protected metal surface. This thought will be illustrated later on in this paper by the reduction of the concentration of dissolved oxygen in the water leaving the hot water tank compared to that entering, and without any wastage of the steel tank being noted. Speller[34] has used the "oxygen drop method" as a direct measure of the amount of corrosion which has taken place in a natural water environment. By measuring the rate of flow and the decrease in oxygen content of the water leaving a certain section of the water system against that of the water entering, the amount of corrosion attack occurring in the section can be closely predicted. When properly designed cathodic protection is applied there is no metal wastage of the steel tank corresponding to the oxygen drop. It is evident therefore that the oxygen has been reduced without the flow of local corrosion currents on the metal surface.

Columbus, Ohio, Experiments

During the past few years a number of hot water tank corrosion experiments have been conducted by C. P. Hoover[35] of Columbus, Ohio. Amongst these tests, the objective being an evaluation of the many methods of corrosion control, was the application of cathodic protection to two of the battery of 30-gallon domestic hot water tanks. One of these two tanks was fabricated of black iron, the other of galvanized iron. The cathodic protection equipment for these tests, which began on June 9, 1941, and were completed on June 9, 1943, was provided by the E. R. P. Corp. The tanks were operated during this interval at a temperature between 140°-150° F. with ten gallons of water being withdrawn from each tank three times daily the first year and twice daily during the second year of the test. Treated Columbus city water used in this test is usually close to saturation with oxygen and has a positive lime saturation index. In the cathodic protection 0.6 and 0.35 amperes were applied to the galvanized and black iron tanks respectively. Fig. 10 illustrates the anode position in respect to the tank. Average oxygen concentrations measured in the effluent of the galvanized and black iron tanks were 1.9 ppm. and 2.4 ppm. respectively. At the end of two years the tanks were cut open and inspected. The observations made were very interesting. In both tanks protection was complete to within ½ tank diameter below the anode. The protected surfaces were covered with a hard thin scale having the following analyses:

Tank Deposit Composition

	Black Iron Tank	Galvanized Tank
SiO_2	3.9%	6.0%
Al_2O_3	4.7%	31.1%
Fe_2O_3	43.2%	10.4%
P_2O_5	0.3%	0.1%
CaO	14.6%	3.5%
MgO	8.1%	0.8%
ZnO	2.9%	30.2%
Ignition Loss—CO_2	11.0%	17.0%

Below this line of demarcation a few pits on the lower 12 inches and bottom of the tank were noted. On re-examining Fig. 10 the reason for this phenomenon can be discovered. The probable current density distribution along the wall of the tank is indicated by distance of the c.d. (current density) line from the wall of the tank. It will be noted that the current density on the tank wall below the electrode decreases rapidly until it is no longer adequate for complete protection. Even so, partial protection is received below the region where the minimum current density requirements are being provided. The walls opposite the electrode received a much higher current density than was actually required for complete protection.

Many objective studies of cathodic protection on practical applications such as this coupled with a basic background on the fundamentals of current density requirements and anode design now provide a more satisfactory treatment of this corrosion problem. For instance, the need for a longer electrode, to provide a more nearly uniform distance of current travel from anode to the surfaces, requiring protection, was illustrated in this test. This case further illustrates the importance of providing the proper current distribution which factor is influenced only by the potential relationships existing between the electrode configuration in the corroding media and the submerged surfaces of the structure being protected. It will be noted that neither galvanizing nor more treatment productive of a scale forming waters can be depended on to provide adequate protection where dissolved oxygen is present. Particularly is this fact evident where hot water corrosion is involved.

Public Service Electric & Gas Company

A cathodically protected 300-gal. hot water generating tank of ¼-in. steel plate at the Kearney, N. J., generating station of the Public Service Electric & Gas Co. has been previously reported on by E. H. Thwaits[36, 37] of the Am. Iron and Steel Inst. The present tank was installed in April, 1942, to replace a tank which had been patched repeatedly because of leaks developing after but fourteen months of operation. In the heater tank 13.5 square feet of copper steam heating coils which are insulated from the main body of the hot water tank are located near the bottom of the horizontal tank. The area of the coils is adequate to heat the volume of water contained within the tank from 60° F. to 180° F. in one hour. In the unprotected tank the pitting was found to be nodular at the top of the tank and, as the wall was examined from the top downwards, it was noted that the corrosion product oozing out of the lower nodular anodic areas streamed down the tank wall like a veil. Under this veil of corrosion product, which masks the metal underneath from the dissolved oxygen in the water, further pitting action was initiated. When the veil-like corrosion product was removed from the wall, long finger-like pits were revealed. The greater intensity

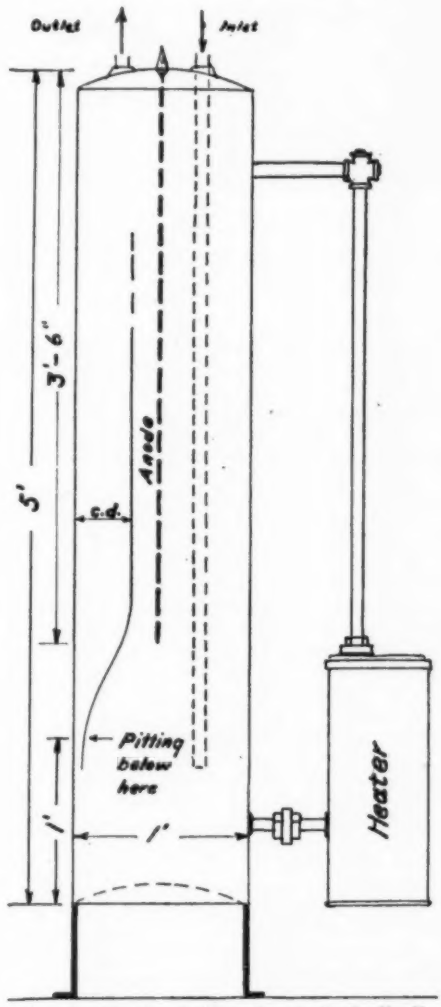


Fig. 1—Sectional Sketch of Cathodically Protected Domestic Hot-Water Tanks, Columbus, Ohio, Studies.

(Adequate protection extended over the wall area below the terminal of the anode only for a distance of one-half the tank diameter—adequate proof of the need for effecting approximately equi-distant current travel from anode to the protected surfaces, if economically effective protection is to result.)

of corrosion noted near the top of the tank probably can be accounted for by the turbulent effect created by the convection current rising from the heating coil striking the top and sweeping down each side of the tank.

The water heated in this tank is Wanaque Reservoir tap water having the following analysis:

Content	ppm.
Temporary hardness	16.3
Permanent hardness	11.1
Total dissolved solids	51.5
Suspended matter	.86
Silica	6.5
NaCl	6.0
M. O. alkalinity	18.0
pH—adjusted by treatment	8.8

Starting in April, 1942, a c.d. of about 1 amp. per 2,000 sq. ft. was applied to this tank and no leak had developed after about 22 months of operation. Although the progress of the corrosion process had been reduced below that which had been previously encountered since, it was clear that corrosion had not been completely stopped as evidenced by the continued formation of rust and the presence of pits. In January, 1944, the current density was increased to 1 amp. per 750 sq. ft., but it was simultaneously revealed through research then being conducted at the Westport Mill of the Dorr Co. that even a higher c.d. requirement was indicated for this tank. In the spring of 1944 a larger rectifier was supplied in consequence and a current density of 1 amp. per 35 sq. ft. (2.86 amps./100 sq. ft.) was applied.

Three months later, upon re-examining the tank, the corrosion product was entirely removed and the surface of the tank was found to be coated with a light powdery-like deposit. The absence of active attack was striking. In December, 1944, the current density was reduced to 1 amp. per 70 sq. ft. (1.43 amps./100 sq. ft.), and in view of the particular corrosion environment it is the author's opinion that this c.d. will provide satisfactory protection. Tests made of the oxygen content of the water entering and leaving the tank were as follows:

Water entering the tank, 13.95 ppm. O_2
Water leaving the tank, 5.85 ppm. O_2

Therefore, the reduction of dissolved oxygen content of the water occurring in tank was 8.1 ppm.

Discussion

In the absence of cathodic protection the actual metal wastage from the tank walls could be predicted from a consideration of the amount of water withdrawn and the reduction of the dissolved oxygen content occurring within the tank. For example the reduction of 8.1 ppm. of dissolved oxygen in 300 gallons of water passing through the tank would represent the degradation of about 21.4 grams of metallic iron from the tank wall, this iron being converted to ferric hydroxide.

The dissolved oxygen in the raw water entering a pressure type of heater will remain in solution except for that which is reduced by the natural corrosion currents (or by the projected current where cathodic protection is applied) since the pressure within the heater will not permit the release and removal of the dissolved gases from the water to the atmosphere.

The current density required to protect an open type hot water heater is usually much less than that required to protect a pressure type of heater. The reason for this will be clearer when it is remembered that the solubility of oxygen and other gases in water at atmospheric pressure decreases with increasing temperature. Therefore, in an open type heater, which is usually vented to the atmosphere, the gases are gradually evolved until they are almost entirely removed at the boiling point. Under conditions where the incoming water is saturated with oxygen it can be seen that the oxygen will remain in the water in a pressure heater whereas in an open type heater a large portion of these gases would be vented to the atmosphere. The heated water thus becomes progressively less corrosive.

Since it has been previously shown that with all other conditions equal, the current density requirements vary with the dissolved oxygen concentration of the water, it becomes apparent that an open type heater will require a lower c.d. than a pressure type heater employed to heat the same water.

New York Central Railroad

A cathodic protection installation in an open type heater at the Harmon, N. Y., yards of the New York Central Railroad has been recently described by E. H. Thwaits.[35] A live steam jet was used to heat the water. It is apparent the live steam used for heating would strip most of the dissolved gases, including oxygen, from the water and, therefore, require a low c.d. for protection of the steel tank. Actually a c.d. of 1 amp./1280 sq. ft. proved adequate for protecting this tank.

Well Pump Corrosion and Cathodic Protection Experiences

The corrosion occurring on the casings, screens and pumping equipment used in deep wells offers a tantalizing problem to those interested in cathodic protection. The failure of the well casing and screen by corrosion usually necessitates the drilling of a new well. Corrosion occurring in the pump bowl, impeller, column pipe and shaft tubing often causes the pump to be pulled prematurely for replacement or repair of the affected parts. There are two types of corrosion currents which influence the attack on deep well equipment. The first is the local corrosion cell type of attack discussed in the author's preceding articles. The second is the man or mechanically created corrosion current which is covered by the broad term—electrolysis. The latter is occasionally found where nearby DC power systems are grounded and current is forced to flow through the water or soil around poorly connected metal joints within the well or to flow from the well through the soil to some adjacent structure possessing a lower potential. Some thought has also been given to the possibility of a rotating pump shaft cutting magnetic lines of force generating direct current which would flow through the shaft and return through the column pipe, etc.

Electrolysis can usually be overcome by a complete survey of the electrical environment surrounding a well and then providing measures indicated by the survey to prevent the forced drainage of current from any metal surface in the well. The local corrosion current cells on the metal surface can be stifled by a projected current from properly positioned anodes within the annular space between the shaft and the column pipe and between the column pipe and the well casing. Other electrodes can be positioned to provide a protective current flow to the inner surfaces of the casing and screen below the pump suction. The corrosion cells caused by dissimilar metals are stifled by cathodic protection. The outside of the casing may be protected against soil corrosion by projecting a current flow through the soil to these surfaces. In view of the complex nature of the interior of the pump bowl and impeller the author does at this juncture not feel that these intricate surfaces can be reached by projected current flow from any practical anode design. This part of the well can best be fabricated of corrosion resistant metals.

Application Experiences

F. P. Macdonald[36] has discussed an oil lubricated deep well turbine pump at La Peer, Mich., whose column pipe was severely pitted when pulled and examined in 1941 after eighteen months of operation. At that time the column pipe was renewed and cathodic protection was applied. Upon re-examining the column pipe after 31 months of operation there was no evidence of attack occurring during that interval. Four other cathodic protection installations in deep wells have been made in Indiana, Louisiana and British Guiana. While these installations are being carefully followed it is yet too early to justify any statement.

Clarifiers and Sludge Blanket Filtration Devices

An unexpected corrosion problem being discovered in most water plants treating raw surface water is the attack of clarifier mechanisms and of the sludge blanket filtration type softeners. This attack is usually not anticipated since in the softening process the water is treated with lime and generally has $CaCO_3$ depositing properties which have been assumed to provide protective properties to submerged steel surfaces. In spite of the positive $CaCO_3$ Saturation Index the corrosion process is active in the presence of such aerated treated water. The freely corroding test specimens shown in Fig. 2 illustrates the type of attack occurring on a water clarifier mechanism in Ohio. The cathodically protected specimens supported against the mechanism structure, shown in the same photograph were completely protected without any corrosion or pits developing during the interval of the test.

An illustration of the type of attack occurring on the submerged surfaces of the Sludge Blanket Filtration type of softener is shown in Fig. 11. The nodular formation of corrosion product (tuberculation) lies over the anodic areas where pitting has progressed beneath these nodules—in a few places even completely through the steel sheet baffles. Cathodic protection is now being applied to many clarifier mechanisms and Sludge Blanket Filtration Type Softeners with very encouraging results.

Dangers in Cathodic Protection Are Few But Require Consideration

The possibility of deleterious effects resulting from properly designed cathodic protection is negligible. It has already been stated in Part I that an excesssive current density will not prove to be harmful to iron. A design consideration that must be made in any cathodic protection installation is the provision for a con-

tinuous low resistance path back to the rectifier from all submerged surfaces receiving a protective current flow. The importance of this is illustrated by the corrosion induced on a poorly bonded pipe joint when current is flowing through the pipe. A portion of the current will leave the pipe and flow through the electrolyte to the adjoining pipe section around the resistance at the joint. Corrosion attack is induced at the pipe joint where the current enters the electrolyte, whereas the adjoining pipe section receiving the same current flow from the electrolyte is being protected. Eliassen and Goldsmith[39] have shown under controlled conditions that grounding of 1.25 amperes of either alternating or direct current at one end of a length of ¾-in pipe and the drainage of this current from the other end of the pipe had no appreciable effect on the quality of the water passing through the pipe. This would indicate that a good current drainage path back to the rectifier from the structure being protected will not influence the normal corrosion processes occurring on surfaces which do not receive a projected current through the corroding media to the metal surface.

Although the fundamental principles of cathodic protection have been well understood for many years and are available in the corrosion literature, the water works field has been fortunate in having had the application of this method of corrosion control to water plant equipment studied and discussed by O'Brien[40], Mabee[41], Norman[42], Knudsen[31], Keith[43], Schneider[44] and by numerous others who have not published their findings. Their observations have contributed much to the better understanding of cathodic protection amongst the men who must battle corrosion in the water and sewage works field.

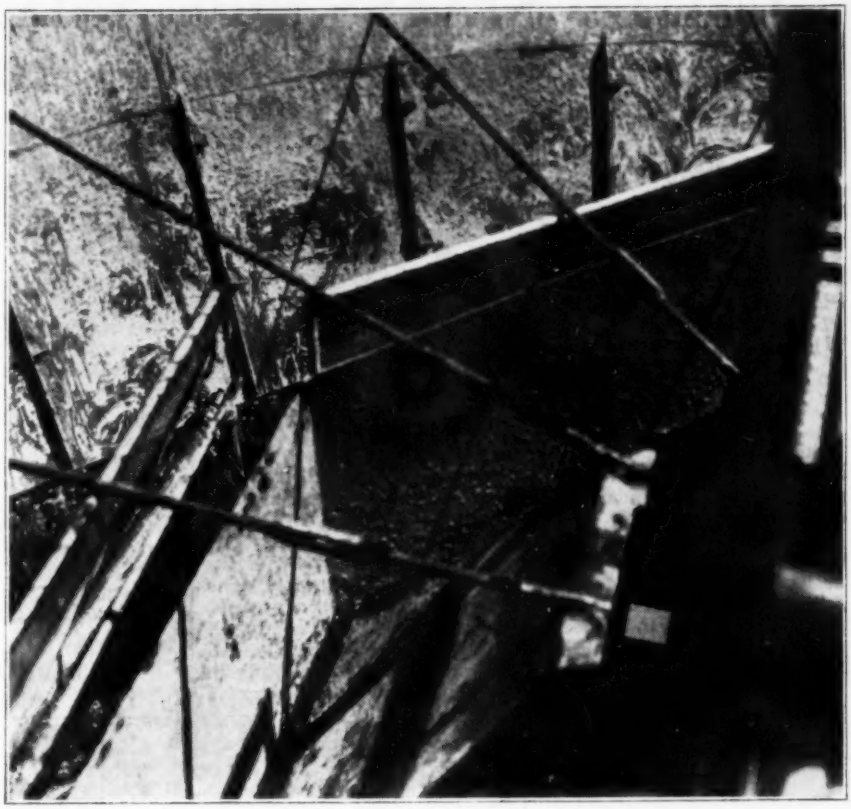


Fig. 3—Metal Work of Sludge Blanket Up-Flow Type of Water Softening Tank (Tuberculation, and pitting beneath these tubercules proceed despite a lime treated depositing water which has not prevented dissolved oxygen attack.)

Conclusions

The application of cathodic protection frequently presents a complex engineering design problem not fully appreciated by many. And, for truly successful results and economy a comprehensive survey of the corrosion environment is the only recommended procedure, except in the simplest cases wherein success seems almost automatic.

Any steel surface submerged in natural waters may be protected when an adequate current density, projected from properly designed anode configurations within the corroding media (and this is of highest importance) is properly distributed so as to stifle the corrosion currents flowing between local cells on the metal surface requiring protection.

All other conditions being equal, the current density requirements for complete protection are a function of the dissolved oxygen content of the water, temperature and velocity.

The deposition of $CaCO_3$, or the existence of other relatively continuous protective coatings on the metal surface, will reduce current density requirements for complete protection.

In regions where ice formation occurs in tanks there is a "corroding season" and an "inactive season." The "corroding season" occurs during the months when the metal is in contact with water, whereas the "inactive season" is the period where the metal surface is protected by an ice film barrier. Protection must be provided during the "corroding season."

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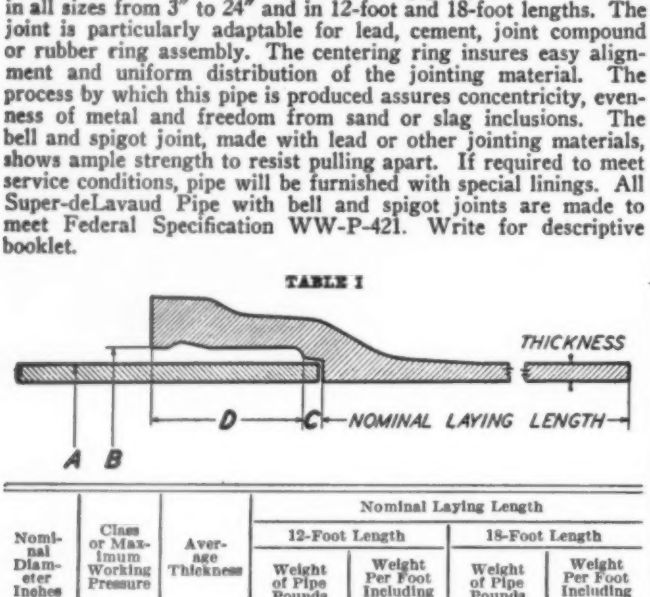
TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8	210	11.7
3	250	.36	155	12.8	230	12.7
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132 0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

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THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26 15
	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
	Standard	18	8.63	.50	8	39.85
8	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

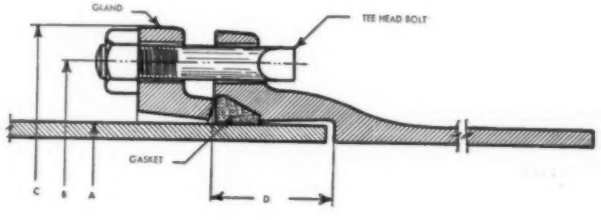
THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

U. S. STANDARDIZED MECHANICAL JOINT



We are now prepared to furnish U. S. Standardized Mechanical Joint Pipe and Fittings in sizes from 3″ to 12″ with parts that are interchangeable with those furnished by other manufacturers of cast iron mechanical joint pipe.

Standardization will eventually be extended to sizes above 12″. In the meantime, these larger sizes will be furnished with our regular U. S. Mechanical Joint as heretofore.

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PITTSBURGH 10, Pa., 4656 Old Boston Rd
ST. LOUIS 1, Mo., 318 North 8 St
•DENVER 2, Col., 1921 Blake St.
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MANUFACTURERS OF

Tegul-MINERALEAD JOINTING COMPOUND

FOR BELL & SPIGOT WATER MAIN

Tegul-MINERALEAD is a radically different jointing compound with advantages not matched in total in any other product for its purpose. Its sulphur base includes, as a plasticising agent, a special olefine polysulphide which contributes these advantageous properties: GREATER ADHESION TO METALLIC AND CERAMIC SURFACES • HIGHER RESISTANCE TO VIBRATION and to MECHANICAL SHOCK AND TEMPERATURE CHANGES • GREATER PLASTICITY and LOWER COEFFICIENT OF EXPANSION • Using *Tegul*-MINERALEAD you may **expect:**

SPEED — *Tegul*-MINERALEAD melts, pours and sets quickly and uniformly (a factor in reducing labor costs). Joints show less than usual initial leakage and backfilling may start at once, thus hastening removal of traffic hazards which arise from open trenches.

CONVENIENCE — Molded in 10 lb. ingots, *Tegul*-MINERALEAD is easier to handle, ship and store. The ingot is impervious to moisture so may be stored outdoors in any weather. Since there can be no change of composition in an ingot, *Tegul*-MINERALEAD reaches you as correctly mixed as when it left our factory.

ECONOMY — *Tegul*-MINERALEAD weighs only 1/5th as much as lead (and goes 3 times as far) saving in shipping costs. 5 ingots to carton makes a handy package. It melts, pours and sets quickly, needs no caulking or deep bell holes and requires no skilled labor. The sum of *Tegul*-MINERALEAD'S advantages make it a *money-saver,* too.

RESISTANCE TO SHOCK — Higher resistance to mechanical and thermal shock promises permanently tight joints. Lines laid with *Tegul*-MINERALEAD in every kind of terrain and meeting every kind of punishment, have served for years without need of attention.

AVAILABILITY — *Tegul*-MINERALEAD is stocked at conveniently located points and is usually available on short notice. Using *Tegul*-MINERALEAD helps conserve lead, a strategic war metal.

HOW *Tegul*-MINERALEAD IS USED

MELTING — *Tegul*-MINERALEAD melts at 248°F., requiring only a slow fire. Care should be taken to avoid direct contact with flame and overheating, which tends to cause the compound to thicken. Best results are had by using furnace designed by the manufacturers of *Tegul*-MINERALEAD.

YARNING — The pipe at Bell and Spigot must be clean and free from accumulations of oil, tar and grease. If jute is employed it should be the dry, braided type.

POURING — See that joints are clean. Use mud on asbestos runner to prevent adhesion to the *Tegul*-MINERALEAD and to seal any leaks. Pour the melted compound slowly through a high pouring gate, using ladles or pouring pot of sufficient capacity to fill the joint at one operation. Add whole or half ingots to replace *Tegul*-MINERALEAD used. It is not necessary to wait for complete melting before pouring more joints. Cut off pouring gate when compound has solidified. Remove runner and joint is complete.

The HYDE-RO Ring

AN IMPORTANT AID IN BELL & SPIGOT JOINTING

Cross section

***SPEEDS STERILIZATION*—First hypochlorite flushing invariably secures negative reaction.**

PROMOTES ECONOMY — FACILITATES REPAIRS EASILY APPLIED

ADVANTAGES IN DETAIL . . .

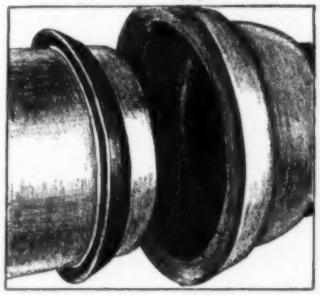
(1) PREVENTS CONTAMINATION — Rubber cannot harbor bacteria nor support their growth internally where water main sterilizing agents cannot reach them. The use of HYDE-RO Rings will prevent continued recontamination that has been traced in many cases to the joint packing.

(2) ECONOMICAL — The cost of HYDE-RO Rings is insignificant compared with the cost of repeated treatments with hypochlorite or the cost of sterilizing and keeping sterile (if it can be done), other types of packing.

(3) CONVENIENT — The installing of HYDE-RO Rings is a simple, easily understood operation. There is no measuring to be done and no cutting. The wrong size cannot be used. Since rings are solid, there are no laps to be inspected to see that they do not occupy too much of the joint space. The same ring fits pipe with bead on spigot or straight end pipe. The narrow iron blade used in caulking the ring automatically slips into the groove in the back.

(4) HOLDS BACK WATER — When HYDE-RO Rings are used, the pouring of wet joints is unnecessary. The rubber ring caulked tightly into place effectively dams off water from leaking valves and permits pouring of dry joints. This is especially important in repair work.

(5) CONVENIENT TO STORE — HYDE-RO Rings are supplied in cartons each containing fifty rings. The packages are light in weight and convenient to handle and store. Rings are manufactured for 4", 6", 8", 10" and 12" cast iron pipe.

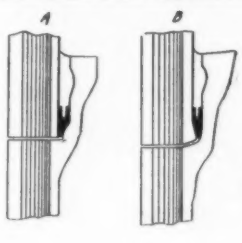


HOW RING IS USED

(1) Stretch the ring over spigot end of pipe with narrow end toward bell.

(2) Slide ring about 1½ inches from end of pipe; then slide the pipe home.

(3) Caulking the ring home, using narrow caulking tool about ⅜" or less in width.



Cross section showing the HYDE-RO Ring caulked into position on plain end (A) and beaded end (B)

HYDRAULIC DEVELOPMENT CORPORATION

MANUFACTURERS OF HYDRO-TITE—A SELF-CAULKING COMPOUND
DRY BRAIDED FIBREX — A SANITARY PACKING — USED LIKE BRAIDED JUTE

MAIN SALES OFFICE:
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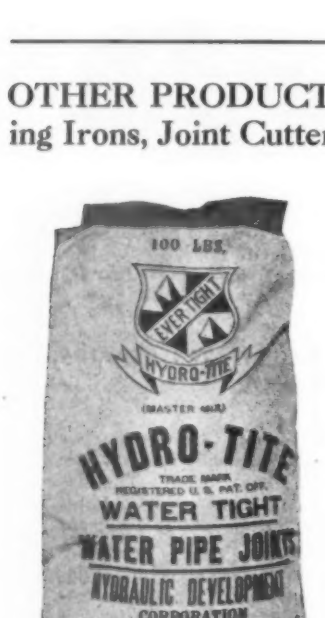
OTHER PRODUCTS — Wood Burning Furnaces, Pouring Pots, Pouring Ladles, Yarning Irons, Joint Cutters, Joint Runners, Open Seam Pouring Funnels.



Properties of HYDRO-TITE

HYDRO-TITE is a black powder composed of selected inert minerals. When melted and allowed to cool, it becomes a strong, tough, metallic mass. Compressive strength is 6,000 lbs. per square inch and its tensile strength is over 650 lbs. per square inch.

Manufacture of HYDRO-TITE

HYDRO-TITE is made in an up-to-date factory with modern machines and by efficient methods. Constant inspection, alert supervision and many years of research by some of the best trained chemical scientists combine to make HYDRO-TITE the leader in its field. This makes possible our continued use of the slogan—"MORE THAN 30 YEARS WITHOUT A FAILURE."

HYDRO-TITE Features

Self-Caulking: HYDRO-TITE is melted by a small fire and nothing is added to make it liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surface of the bell and the spigot for the entire length of the joint. HYDRO-TITE requires no caulking.

Self-Sealing: HYDRO-TITE joints are, under normal conditions, perfectly tight when pressure is first applied. Any leak or seep from a new joint will soon be stopped by the self-sealing quality of HYDRO-TITE. Even leaks occurring when pouring over-heated HYDRO-TITE will seal themselves within a day or two. "Less leakage from the start and quicker sealing qualities in case of small leakage."

Ready for Immediate Use: There need be no waiting time after pouring a joint with HYDRO-TITE. It solidifies at once upon contact with the pipe and is ready for regular pipe service.

RESISTS VIBRATION: HYDRO-TITE can be used anywhere. It is in service on pipe lines carried over bridges subjected to heavy automobile trucking, trolley cars and continuous railway traffic.

DRY BRAIDED FIBREX

A Sanitary Packing used in Jointing Bell and Spigot Pipe for Water Mains—Sewer Mains—Soil Pipe.

FIBREX is the answer to the constant demand by Sanitary Engineers for a packing which will not breed bacteria when used in water mains. Fibrex is a paper packing treated with a special water repellent which keeps the Fibrex sterile and prevents it from disintegrating. It has a hard twisted core with a basket weave covering and packs in a joint exactly the same as braided jute.

FIBREX is 30% lighter in weight than dry braided jute and is put up in 60-pound reels. Each reel will take the place of over 90 pounds of braided jute and the cost per pound is approximately the same for both Fibrex and jute. This effects a 30% saving in cost.

FIBREX was designed for use with Hydro-Tite and other self-caulking compounds. However, it is entirely suitable for joints made with lead, also for Sani-Tite and other asphalt sewer joint compounds.

Hundreds of thousands of pounds of dry braided Fibrex are already in service on water lines throughout the country. It has the approval of the War Department at Washington, several different Area Engineer Offices of the War Department, the Departments of Public Health in some of our larger states and numerous Water Departments.

Laboratory tests have been made by Skinner & Sherman, Inc., Chemists and Engineers, Boston, Mass., and their report shows that Fibrex does not breed bacteria, as is characteristic of jute, in both sterile and contaminated water.

FIBREX is made in ⅜", ½" and ⅝" sizes The ½" size is used on nearly all joints. The ⅜" and ⅝" sizes are used on thick or thin joints, as in case of some specials or changing over from one class pipe to another.

CHARTS FOR DETERMINING EQUIVALENT PIPES AND LOOP FLOW DISTRIBUTION

By H. W. CLARK
City Manager, Niagara Falls, N. Y.

IN THE determination of flows in pipe network systems by the Hardy Cross method, it is often desirable, for simplification of the work, to reduce parts of the system to an equivalent size pipe, and use the equivalent value in the computations.

For a quick and easy method of computing equivalent pipes and determining the percentage of flows in pipe loops, the accompanying charts have been prepared.

Method of Preparing Charts

The Williams and Hazen formula[1] was used with the following quantity notations:

The basic formula is $V = CR^{.63}\ S^{.54}\ 0.001^{-0.04}$

Flow $Q = VA = CR^{.63}\ S^{.54}\ 1{,}318A.$

where
- Q = Flow in cubic feet per second (c.f.s.)
- C = Williams & Hazen pipe coefficient of roughness.
- R = Hydraulic radius of pipe in feet.
- S = Slope of pipe = h divided by 1.
- A = Area of pipe in square feet = $.7854D^2$
- D = Diameter of pipe in feet
- h = Head loss in pipe considered
- L = Length of pipe considered in feet.

Substituting in the above formula, we obtain—

$$Q = C\ 1.318\ (.25)^{.63}\ .7854\ D^{2.63}\left(\frac{h}{L}\right)^{.54}$$

as the constants are common to all pipes and in equivalent pipes or loops the head loss, h, is the same for each, Q is proportional to $\frac{D^{2.63}}{L^{0.54}}$ for pipes of equal roughness.

This is the same method given by James A. Conklin in an article in *Engineering News-Record*[2] in which he designated the quantity $\frac{D^{2.63}}{L^{0.54}}$ as the Pipe Factor, although he used the Chezy formula with the factor equal to $\frac{D^{2.5}}{L^{0.5}}$.

In order to construct the charts the $D^{2.63}$ values for nominal diameters of cast iron pipe were computed and spotted on the Y axis of logarithmic paper, then through each of these points were drawn the parallel lines $1/L^{0.54}$ using 1,000 foot units for L. At the left of the diagram is read the factor for any corresponding pipe diameter and length.

For convenience in use two charts on 8½x11 inch logarithmic paper have been prepared rather than preparing a large unwieldy chart. Obviously the charts overlap and the choice of chart in the overlapping sections depends on the length of pipe involved in the computation.

Demonstration of Chart Use

In demonstrating the use of the diagrams, some published examples will be used, as most readers will probably be familiar with the examples.

Example A

In D. R. Taylor's excellent article on the Hardy Cross method, in *Water Works and Sewerage*,[3] he uses the following circuit:

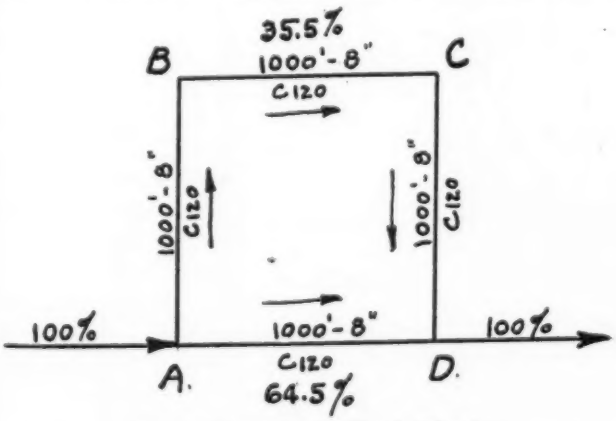


Fig. 1—Example A—Simple Circuit

The direction of flow is indicated by the arrows. From Chart I, Factor (F) is determined as follows: Look for the 1000 foot line at bottom of diagram, follow this line vertically to diagonal marked 8 in., from this intersection point follow horizontally to the left scale and read .345. In the same manner follow the 3000 foot line vertically to the 8 in., diagonal, thence left from that point and read .19.

Add these two quantities and divide the sum into each, obtaining the percentages shown. These percentages check those of the original problem, after its two calculations.

The sum of these factors, 0.535, intersects the 8 in. diagonal line at 445 feet.

Factor F = 0.535 = 445 ft. in 8 in. pipe, the equivalent pipe.

AD = 1000 ft. of 8 in.,	F = .345	64.5%
ABCD = 3000 ft. of 8 in.,	F = .19	35.5%
	.535	100%

Inasmuch as the Q's are expressed in percentages where the head losses are desired, Q may be used as g.p.m., c.f.s. or m.g.d.

We can now check the above problem using Hardy Cross factors from Taylor's article,[3] Fig. 2.

The k for 1000 ft. of 8 in. with (C 120) = 6.0; for 3000 ft. of 8 in. with (C 120) = 18.0.

The formula for head loss by Doland's formula[4] is

$$h = \frac{k}{100{,}000}\ (\text{gpm.})^{1.85}$$

This formula can be simplified by taking $100^{1.85}$ out of the parenthesis and dividing by 100,000; it then can be written

$$h = k\ (.05012)\ (.01\ \text{gpm.})^{1.85}$$

Calling the total Q, 1000 gpm. the flow in AD will be 645 gpm., in ABCD 355 gpm. and in the equivalent pipe 1000 gpm.; then the head loss in the paths of the loop and in the equivalent pipe is found as follows:

Path AD	h = 6 (.05012)	$(6.45)^{1.85}$	= 9.45
Path ABCD	h = 18 (.05012)	$(3.55)^{1.85}$	= 9.43
Equiv. pipe 445 ft. of 8 in.,	k = 6 (.445)		= 2.67
	h = 2.67 (.05012)	$(10.)^{1.85}$	= 9.44

This agreement of the head loss "h" appears close enough for any practical purpose.

Example B

Three parallel pipes are just as simple to figure as shown below, using the same steps as in Example A

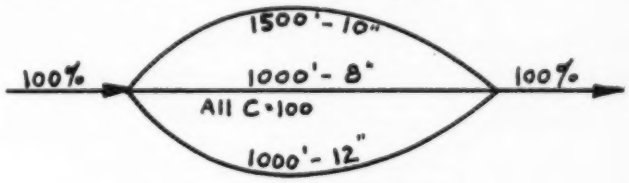


Fig. 2—Example B—Parallel Pipes

1500 ft. of 10 in.	F = .50	=27.1%
1000 ft. of 8 in.	F = .345	=18.7%
1000 ft. of 12 in.	F = 1.000	=54.2%
	1.845	100%

F 1.845 = 135 ft. of 10 in.; 325 ft. of 12 in.; or 1300 ft. of 16 in.

These values may be checked by the same method given for finding h in Example A.

Example C

The chart values check closely the values given in tables computed by W. E. Howland and F. Farr, Jr.[5] shown by the following example.

Take 500 ft. of 8 in. pipe F = .5 from Chart I.

Reading across the .5 line where it intersects the 10 in., 12 in., and 16 in. pipe lines we find the equivalent lengths to be

10 in. = 1,480 ft.
12 in. = 3,600 ft.
16 in. = 14,600 ft.

From the Howland & Farr table, page 238[5], mentioned above, we find the equivalent values of 1 ft. of 8-in. pipe in the other sizes to be

1 ft. of 8 in. = 2.965 ft. of 10 in.
1 ft. of 8 in. = 7.205 ft. of 12 in.
1 ft. of 8 in. = 29.25 ft. of 16 in.

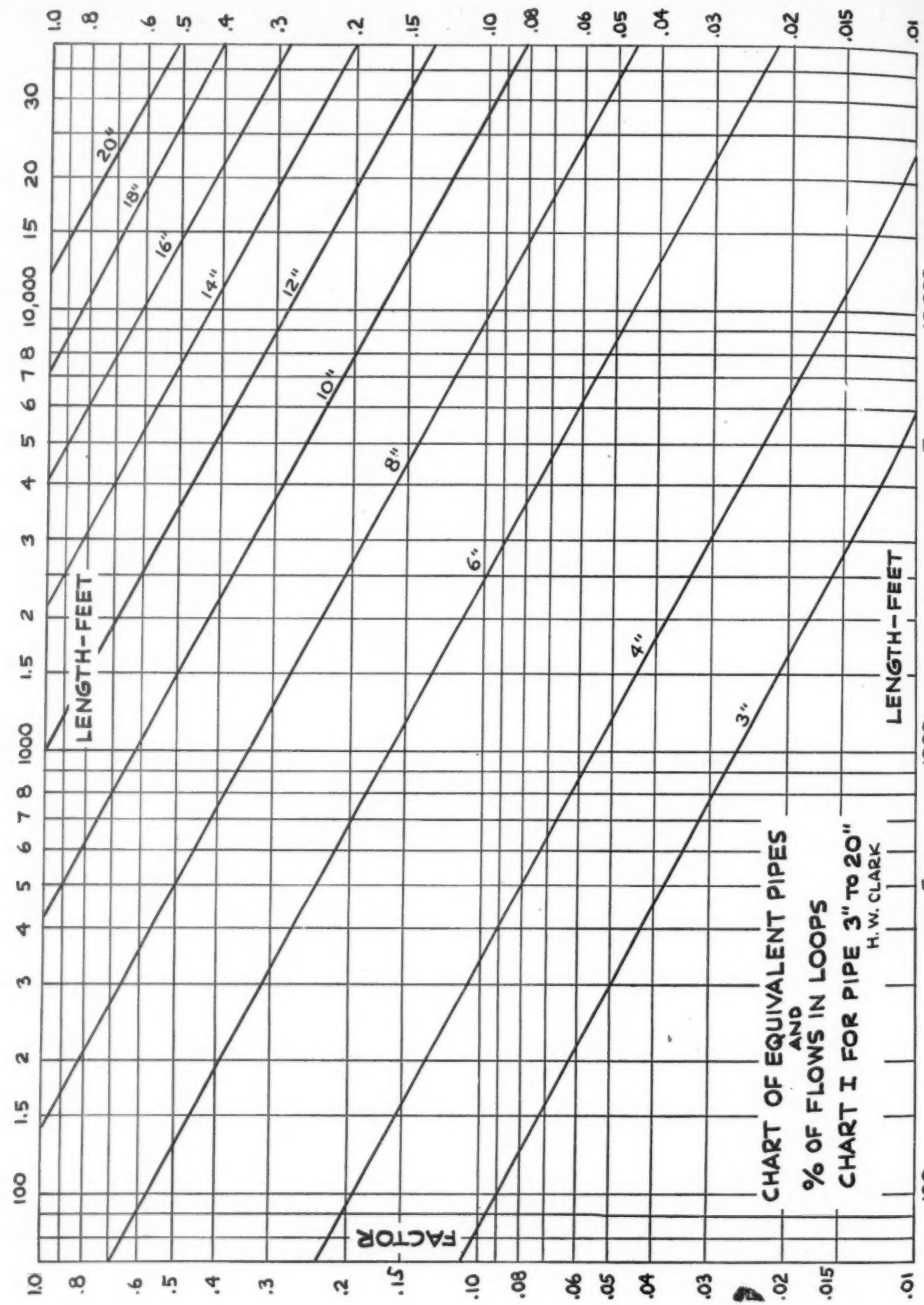


Chart I—Equivalent Pipes and Per Cent Flows in Loops for Pipes 3-in. to 20-in.

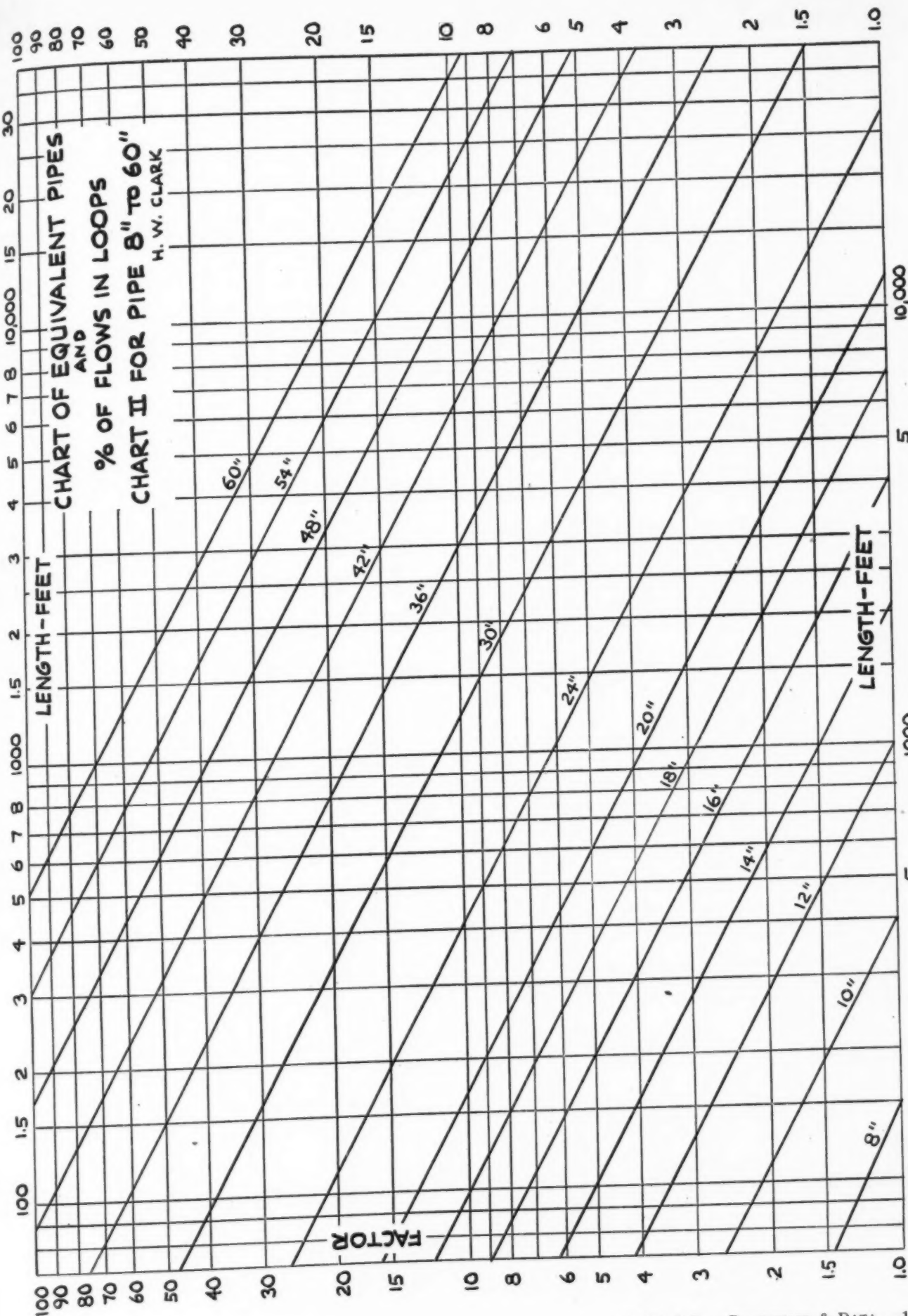


Chart II—Equivalent Pipes and Per Cent Flows in Loops for Pipes 8-in. to 60-in.

Multiplying each of these values by 500 we obtain, respectively, 1482.5 ft. of 10 in., 3602.5 ft. of 12 in. and 14625 ft. of 16 in., which, considering the size of the chart readings, is a pretty fair check.

Example D

Pipe circuits with crossover pipes and intermediate take outs are not subject to exact analysis, but many of them can be closely approximated and many steps saved, as the following problem will show. It is not claimed, however, that all circuits will work out as well, for with complicated systems good judgment and experience in the method of computation will be the best guide.

Let us take D. R. Taylor's two-circuit problem from the same article[3] previously mentioned.

Using the same steps as outlined in Example A the following data are obtained:

AB = 3000 ft. of 12 in.	F = .55	56.7%
AFES = 5000 ft. of 12 in.	F = .42	43.3%
	.97	100.0%

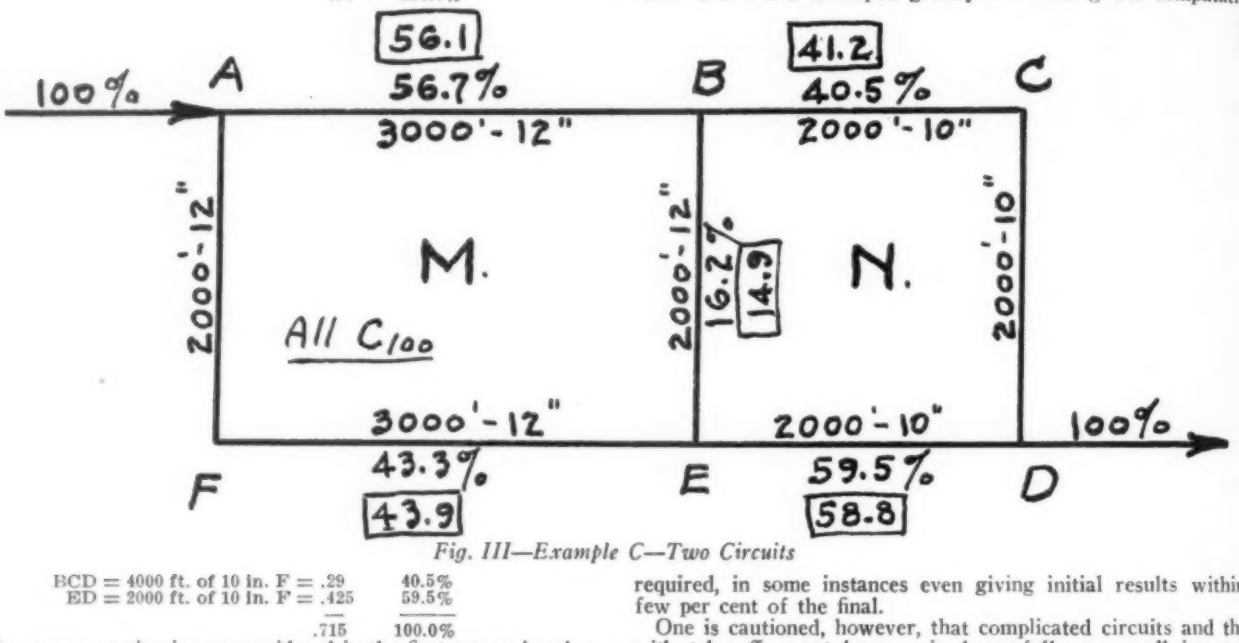


Fig. III—Example C—Two Circuits

BCD = 4000 ft. of 10 in.	F = .29	40.5%
ED = 2000 ft. of 10 in.	F = .425	59.5%
	.715	100.0%

The crossover pipe is not considered in the first approximation, only the outside circuit.

Place the percentage flows as computed on the diagram and we find BE to be 16.2 per cent.

Computing the circuits by the Hardy Cross method, a correction in M of —.6 per cent clockwise is found, and in N of +.7 per cent clockwise on the first computation. These are within .1 per cent of the final value.

The pipe BE has two corrections, both being minus, with the final value of 16.2—.6—.7 = 14.9.

Example E Where C Varies in the Loops

In the foregoing examples the C of all pipes has been considered equal but pipes of different C values can also be compared by converting both to the same C and proceeding as demonstrated.

Consider the first problem again, using C = 100 for AD and C = 120 for ABCD.

The change can be either way," the method to pursue as follows:

Change AD (C = 100) to C = 120 by multiplying the length 1000 ft. by $\left(\frac{120}{100}\right)^{1.85} = 1000 \times 1.4 = 1400$ ft.

If the change had been to C = 100 for the C = 120 pipe. ABCD = 3000 ft. (C = 120) would have been divided by 1.4 and the resulting length used with the 1000 ft. for AD and C = 100 for both.

We will use the C = 120 values, then

AD 1000 ft.	(C = 100) = 1400 ft.	(C = 120);	F = .288	60.2%
ABCD 3000 ft.	(C = 120) = 3000 ft.	(C = 120);	F = .190	39.8%
			.478	100.0%

Equiv. pipe F (.478) = 550 ft. 8 in. (C = 120)

Check computations.

AD k for 1400 ft. of 8 in. (C = 120) = 6 (1.4) = 8.4
ABCD k for 3000 ft. of 8 in. (C = 120) = 6 (3.0) = 18.0
Equiv. pipe k for 550 ft. of 8 in. (C = 120) = 6 (.55) = 3.3

Assuming 1000 gpm total flow.

AD h =	8.4 (.05012)	$6.02^{1.85} = 11.61$
ABCD h =	18. (.05012)	$3.98^{1.85} = 11.60$
Equiv. Pipe h =	3.3 (.05012)	$10^{1.85} = 11.68$

It will also be noted that the k value for 1400 ft. of 8 in. (C = 120) is 8.4 which is the same value for 1000 ft. of 8 in. (C = 100) 8.4 × (1.0) from Fig. 2[3] values of k.

For changing from C = 100 to any other value of C, multiply by the following factor; if changing from C = 120, etc., to C = 100, divide C = 120, etc., by the factor; these factors are simply $\left(\frac{Cx}{C100}\right)^{1.85}$

Where C =	90	100	110	120	130	140
f =	.823	1.0	1.193	1.40	1.625	1.863

Conclusions

The author has used the foregoing method in computing circuits and found it helped greatly in reducing the computations required, in some instances even giving initial results within a few per cent of the final.

One is cautioned, however, that complicated circuits and those with take-offs must be examined carefully, as small increment corrections will sometimes throw them out of balance instead of toward convergence. Large pipes with low resistance factors in loops with smaller pipes of high resistance are very tricky in adjusting flows.

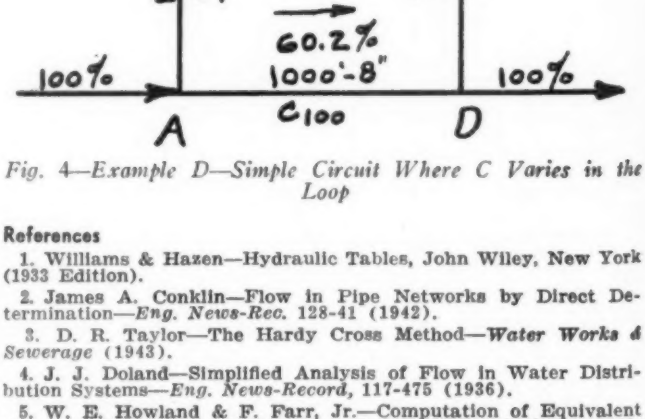


Fig. 4—Example D—Simple Circuit Where C Varies in the Loop

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1. Williams & Hazen—Hydraulic Tables, John Wiley, New York (1933 Edition).

2. James A. Conklin—Flow in Pipe Networks by Direct Determination—*Eng. News-Rec.* 128-41 (1942).

3. D. R. Taylor—The Hardy Cross Method—*Water Works & Sewerage* (1943).

4. J. J. Doland—Simplified Analysis of Flow in Water Distribution Systems—*Eng. News-Record*, 117-475 (1936).

5. W. E. Howland & F. Farr, Jr.—Computation of Equivalent Lengths of Parallel Pipe Systems—*Jour. AWWA*, 33-237 (1941).

6. Hardy Cross—Analysis of Flow in Networks of Conduits or Conductors—*Univ. of Illinois Bul.* No. 268 (1936).

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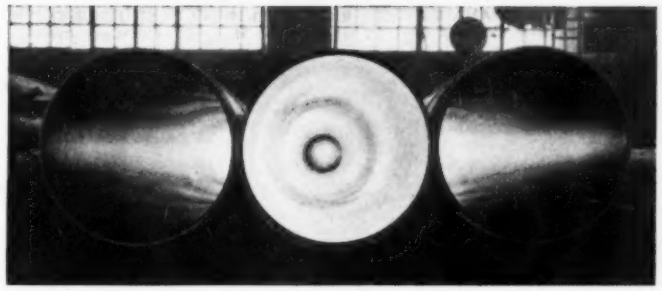


BITURINE AKWALINE ASSURES HIGH "C" FACTOR

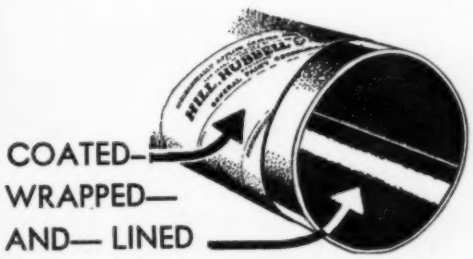
BITURINE AKWALINE ENAMEL is melted and heated in mechanically agitated and thermostatically controlled bitumen kettles. For lining STEEL PIPE, the duration of heating is kept to a minimum by the rapid application to the inner surface of the horizontally positioned power rolled or spun pipe. The feed line placed at the bottom of the pipe, disperses the flow of hot enamel in quantities sufficient to build up a multiple application thus covering and protecting the inner wall of the pipe with a smooth, resilient surface.

BITURINE ENAMEL COATING and KRAFT PAPER WRAPPING

BITURINE AKWALINE PRIMER is the first process in the protection of the pipe surface. Rapidly rotating weighted bristle brushes force the primer into every irregularity of the steel structure. BITURINE AKWALINE COATING—AND—WRAPPING is also machine applied; again minimum duration of heating is attained by exceptionally rapid application—After the second coating is applied there are no skips, holidays or bubbles, the felt wrapper is applied by flooding the inner surface with the hot coating, before it is wound on the pipe under fixed mechanical tension. Another coating is applied before the protective cover of 80 lb. Kraft Paper is spirally wound in place. HILL-HUBBELL AND COMPANY printed on the Kraft paper covering stamps it a product of worthy CRAFTSMANSHIP.

STEEL PIPE HAS MANY OUTSTANDING ADVANTAGES

For many years STEEL PIPE has been used for water mains—It is particularly applicable, because of its shatter-proof strength, flexibility, ductility, long lengths, lower installation costs and greater enduring capacity. With HILL-HUBBELL MODERN methods of pipe protection applied to it, it gives long service at low maintenance cost.



HILL-HUBBELL PIPE PROTECTION MEETS A.W.W.A. 7A.6

COATING — AND — WRAPPING — AND — LINING with BITURINE AKWALINE PRIMER AND ENAMEL complies fully with A.W.W.A. Specifications 7A.6.

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

22nd Floor, 30 Church St., New York 7, N. Y.

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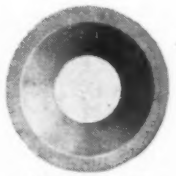
Before Cleaning

The NATIONAL METHOD

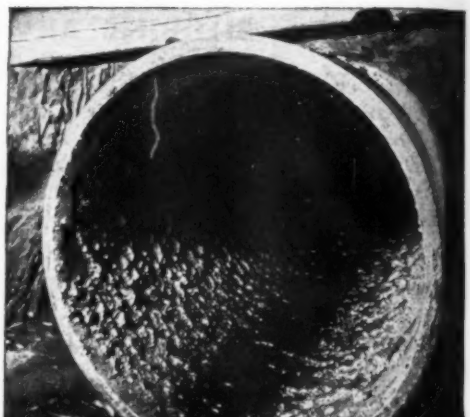


After Cleaning

30" Main in a Midwest City Before Cleaning

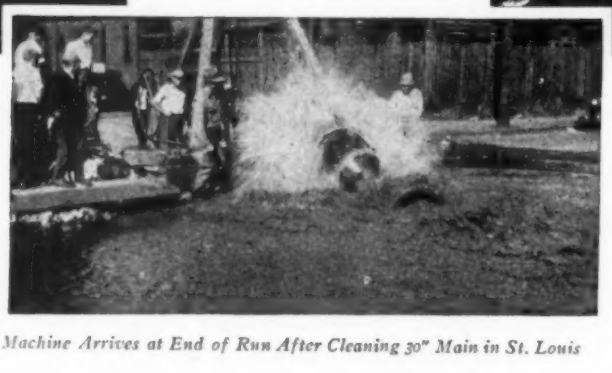
WHAT YOU GAIN FROM MAIN - CLEANING by NATIONAL

1.—More Water
2.—Better Water
3.—Higher Pressures
4.—Lower Pumping Costs
5.—Lower Fire Insurance Rates
6.—Satisfied Consumers



When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable

Our experts can make valuable suggestions about the best, quickest, and most economical ways to restore 95% of your pipe's original capacity.



Machine Arrives at End of Run After Cleaning 30" Main in St. Louis

To put your water distribution system into first class condition for maximum service get in touch with our nearest office.

THE ONE place you want experienced service is in your water main cleaning. Too much depends upon your uninterrupted water supply to justify taking chances. 38 years of successful cleaning experience are at your command when you employ National to do this important work. All the improved technique that comes from being America's leading water main cleaners for over a third of a century is at your disposal.

Mains down over 20 years easily can lose 50% of original capacity through encrustations and foreign matters, which reduce pressure, quantity and quality of water, as well as increasing pumping costs and keeping insurance rates up. Such mains can be cleaned the National way in from 5 to 7 hours, at night if necessary. Service can be resumed very quickly in any emergency.

Information regarding any of the hundreds of successful cleaning projects will be supplied upon request.

GUARANTEED TO RESTORE 95% ORIGINAL CAPACITY

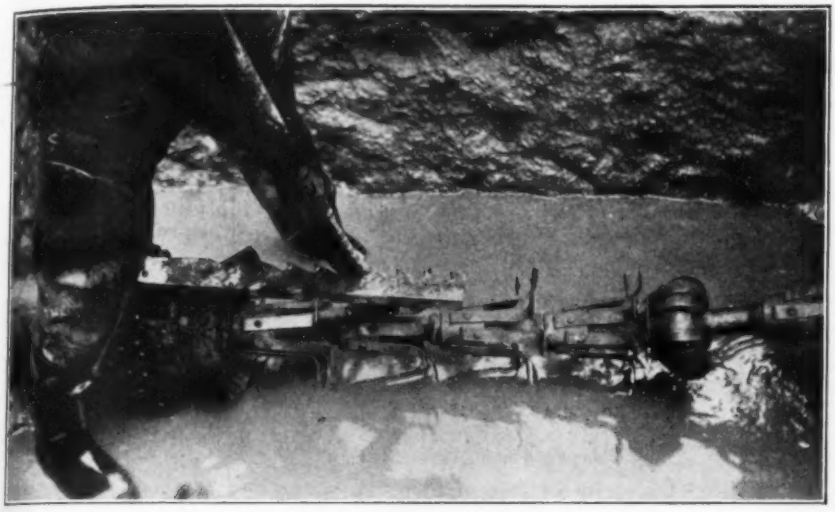
WATER MAIN CLEANING

Some Recent Experiences and Results

By WM. S. STAUB, Engineer

West Virginia Water Service Co.
Charleston, West Virginia

WE HAVE just completed main cleaning projects at three of our properties in this state. This, our first adventure in this kind of main restoration, will serve as index of merit of the process. We have definitely raised the flows and pressures in those mains that have been cleaned and, in cases of the transmission mains, the pumping cost per million gallons has been reduced.



"Jacking-In" Operation
About half of a cleaning tool jacked into an 8-in. main. It will travel under its own "steam" by main pressure turned in behind it.

The purpose of this paper is to present our ideas of main cleaning, why we clean mains, what results we have had, the cost per foot to clean; to give a general description of the procedure and to observe what happens in a cleaned main.

In years gone by, when there was no water treatment or when the practice was in its infancy, beyond taste and appearance other characteristics of the water were given little thought. Therefore the distribution system suffered, due to lack of knowledge of corrective treatment. Th edeposition of the solids and the tuberculation reduced the area of the pipe and, therewith, the amount of water that would flow through the pipe under pressure available. Consequently, today, when there are complaints of poor pressure, or when increased fire flow is in demend, we are faced with the problem of main replacements or improvement of existing mains. Although the exterior of the pipe is usually as good, practically, as the day it was installed, the interior may present a scene comparable to the stalagmites and stalactites of the eastern caverns. If such choking deposits can effectively be removed from the pipe and the carrying capacity appreciably restored there will be a great savings over replacements, even though the latter be necessary eventually..

A dirty main is definitely a liability. From the operating standpoint a dirty transmission main consumes many kilowatt hours of power due to the added friction. Kilowatt hours in turn cost money, which in turn increases operating expenses. A dirty main is a great handicap to the fire departments, due to insufficient quantities of water. Poor pressure complaints from consumers are not soothing melodies to a superintendent's ears. Consequently, everyone suffers from the effects of tuberculated pipes.

Locating the Trouble

When a main is suspected of being tuberculated, or when we find that the operating head on a pump is much greater than the static head plus the calculated friction head for new pipe, it is time to find the trouble. The distribution main is isolated in such a manner than all water going to a certain area must pass through the section of pipe to be tested. Then, in the early morning hours, the calibrated pressure gauges are placed along the line and a hydrant is opened at the end of the line. The amount of water is measured with a pitot-tube, the pressure drop is recorded and the loss per 1000' or the value of "C" is determined. (For details of the method see "Hydrant Discharge Measurements," page 183. Reference and Data Number of Water Works and Sewerage, May, 1939.)

We admit this method of determining "C" is not as accurate as secured by Pitometer tests, but we feel that a reasonably accurate value is obtained if precautions are used. In the case of transmission mains, by determining the efficiency of the pumping equipment, static head, operating head, power consumed, water pumped, it is possible to get a very good check over any period. (For "A Simple Method for Checking Pump Efficiencies" see page 445, November, 1939, Water Works and Sewerage.)

Cleaning Procedure

The largest pipe which we cleaned was 10" cast iron. The 10" and 8" pipe was cleaned with the pressure cleaning machine, which uses the water pressure to push the device through the pipe. This machine (see pictures) is about 6' long, composed of five cutting heads and two pistons. The heads are "vertebrae" upon which are attached, around the circumference, the cutting blades. The

The "Carrier"
A rod with leather piston cups is used to thread cable through 4-in. and 6-in. mains.

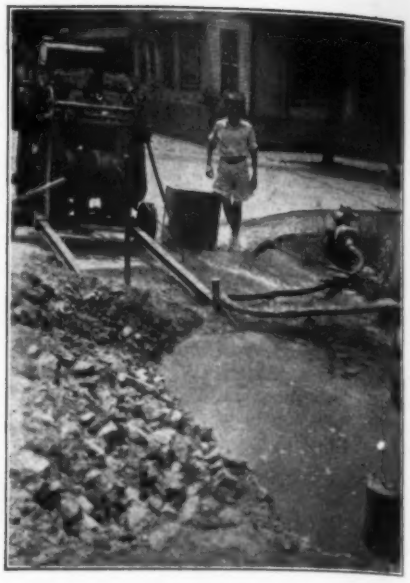
blades are of spring steel. There are two flexible "pistons" from which the machine gets its drive. There are adjustable ports through the pistons, which we can set to control the volume of water passing the machine for sweeping the debris ahead and, at the same time, to prevent the machine from moving too rapidly. Closing the ports naturally gives added driving power for the tougher jobs. The pistons and cutting heads are on a flexible spring and cable type of shaft. Its flexibility will allow the machine to pass a standard 90° bend. Contrary to the belief of many, the machine does not take on any spiral or whirling motion in its travel.

Cleaning 8 and 10 Inch Mains

The main is isolated and a section of pipe is removed at the point of beginning. This section should be long enough to give ample working room for inserting the machine. The machine is then jacked intothe pipe (see cut) and the pipe permanently jointed either by solid or Dresser sleeves. At that point at which we wish the machine to emerge the pipe is again cut. A short section is removed and bell and spigot fittings are used to rig a riser. Usually this is done with a 45° bend and a short piece of pipe. The joint need only be juted and chained. The purpose of the riser is to discharge the debris on top of the ground, rathre than in the trench. When the riser is rigged the pipe is all ready. The valve on the main is opened slowly to secure the proper amount of water and the machine begins to move. The machine generally moves about 100 feet per minute and it is possible to follow its travel through the line, as the water passing the pistons and the scraping blades is audible at the surface. Generally the water emerging from the riser will only be colored until the machine gets within about 300 feet, then the water is thick and black. The solid material may issue from the pipe like sausage, if the encrustation is marked. In the case of the 3900' of 10" line in South Charleston (W. Va.) there was an estimated one and one-half tons of solid material which came from the pipe. The machine will generally lodge in the riser pipe due to so much debris, and has to be helped out. When the machine has reached its destination (after only one trip through in most cases) the riser is dismantled, the main flushed, jointed, and placed in service.

Dollar Losing Debris

Some of the 1½ tons of solid material swept out of 3,976 ft. of 10-in. transmission main, to reduce pumping cost $2.37 per million. (See accompanying tables of data and costs.)



The Safety Winch

Pulling cleaning tool through a 4-in. line. In such operations the debris collects in the ditch, which is dewatered with the small portable pump alongside.

A Small Line "Make-Up"

In which the "carrier" with threading cable attached has been inserted in 4-in. main and is ready to travel.

Cleaning 4 and 6 Inch Mains

In the case of 6" mains, where they are not so dirty, these may be cleaned by "pressure shots" as described for larger sizes of pipe. In one case where the pressure was low a booster pump was used to supply increased pressure for a 6" "pressure shot." However, generally 6" mains must be cleaned the same way as 4" pipe, which I will now describe.

In cleaning 4" mains the section to be cleaned is isolated and the main opened at both ends. At the beginning point a small cable is attached to a "carrier" and inserted into the line. The "carrier" is a short rod with leather pistons. The main is then jointed at this point with a portable coupling known as a "make-up." This "makeup" has a gland in the top through which the small cable may be fed. The water is then turned on behind and the water velocity takes the "carrier" and the small cable to the other end of the pipe. This small cable is then used to pull the big cable back to the point of machine insertion. The makeup is removed, the cleaning tool clamped to the large cable (see cut), the main permanently jointed, the water pressure turned on, and the cleaning tool is pulled through the pipe by a gasoline driven winch. This process is much slower than the pressure method and great care must be exercised to prevent breaking the cable and losing the machine. In this case a very slow speed is used. The winch automatically releases the clutch when the tension or pull becomes too great. This generally happens when the cleaning tool caught some joint lead or a bad obstruction. When the cleaning tool emerged the main was flushed and permanently jointed.

Obstacles Encountered

In pressure cleaning the drive of the machine is dependent upon the velocity of the water acting on the pistons, and in the event the machine encounters a cross increasing on the branches it will generally stop. In other words, in cleaning an 8" pipe, if at an intersection an 8 x 10 inch cross is present the machine will hang. This is due to the pistons expanding and allowing the water to pass it instead of driving the machine.

If the wash water passing the machine is not sufficient to carry the debris ahead the machine will be fouled. We encountered one 8" main in which the machine would move a short distance, then stop. After the wash water had moved the material ahead the

machine would move again. This happened on a long line where wash water was insufficient and blowoffs were too far apart. The machine had to re-run through this section and I am of the opinion that part of the debris was deposited behind the machine during the first cleaning.

Short radius bends with valves on one side caused several cuts to be made.

Insufficient pressure was a jinx on one job. We were cleaning a 10" main from the reservoir down the hill. The pressure at the point of beginning was only 17 pounds. Thus it was necessary to fill the line with water and bleed it rapidly at the bottom of the hill, thus creating a vacuum. When this was done it was then impossible to keep up with the machine.

Poor joints were responsible for a number of worries—poorly juted joints where the lead had run into the pipe. There were chunks of lead removed weighing 50-75 pounds, old pump gaskets, coil springs, timbers, rocks and, in one case a piece of 1½" pipe about 6 feet long. These had probably entered the system years ago when reservoirs were uncovered or when the pipe was laid.

An Ounce of Obstruction; A Pound of Cure

This section of 8-in. pipe didn't look "too bad," but results after cleaning showed that it was. Proof found in the accompanying tables of data, revealing the "before and after" story, is more convincing than many words about it.

Discoveries and By-Product Values

At Hinton practically the entire system was cleaned. As a result, the method in which tie-ins are made, the fittings, and location of mains were definitely established. I know that our superintendent there can now point out on the ground just what is at every intersection, because he made intersection cards accurately during the cleaning.

There were cases when a pipe which was supposed to be was not and vice versa. Old valves were found, some with box and all gone, some with stem broken and some found partly closed.

If anyone operating a water system, which has been in service for a number of years, attempts a job of main cleaning, he will probably be surprised at a great many things found. And, from the operating standpoint, the knowledge gained during cleaning of mains may well save a few nights sleep to the superintendent.

Conclusions

We feel that our main cleaning jobs have done a lot of good. Those who have seen the mains before and after know that flows have definitely been improved. Just how long this pipe will remain clean is another question, but we expect to keep a close check on the cleaned mains. In fact, we are taking daily samples at all points where we cleaned and are recording the pH, alkalinity and CO_2. Periodic flow tests will also be made to ascertain to what degree the main is tuberculating. We are trying to control our corrective-water treatments accordingly.

We do know that the fire flows have been greatly increased and that once weak hydrants are again gushing brisky. On transmission mains there have been definite and pleasing reductions in power consumed.

Costs and Cleaning Data

In the accompanying tables something of the data pertaining to cleaning operations and costs are presented for the benefit of those interested.

TABLE 1—Charleston Main Cleaning

Item	Pipe 6" Kanawha St.	Pipe 8" Va. St.	Pipe 10"** So. Chas.	Pipe 10"-8"** Nitro Line
Contract of Cleaning	$134.80	$271.70	$397.60	$1,488.95
Material Cost	6.19	48.86	138.29	250.40
Labor Cost	65.86	186.80	188.14	888.09
Total Cost	206.85	507.36	724.03	2,627.44
Number of Feet Cleaned	1348	2717	3976	29779
Cost per Foot	$ 0.1535	$ 0.187	$ 0.1823	$ 0.0834

* This cost does not include 8" temporary steel line which was laid. The rental of pipe, placing and removing cost $1,757.75 for 4200'. If this were added to the above the cost per foot for cleaning the 10" main would be $0.625.
** The 10" and 8" main is a transmission main and was cleaned as one unit. Therefore there was no breakdown in cost.

TABLE 2—Charleston Main Cleaning (Transmission Main)

Location	Size	Feet of Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
South Charleston	10"	3,976	66	130*
Nitro-Dunbar	10"	10,679	49	130
Nitro-Dunbar	8"	19,100	49	126
Charleston-Virginia St.	8"	2,717	—	138
Charleston-Kanawha St.	6"	1,348	—	115

* Yielding an estimated savings in pumping cost (power) of $2.37 per M.G. for the South Charleston main.

TABLE 3—Hinton Main Cleaning (Total Cleaning Costs)

Item	10" C.I.	8" C.I.	6" C.I.	4" C.I.
Contract of Cleaning	$177.40	$ 546.90	$255.60	$ 675.80
Labor Costs	42.92	238.33	185.60	376.86
Material Costs	44.25	245.54	189.30	301.96
Total Cleaning Cost	264.57	1,030.77	630.50	1,354.62
Cost per Foot	0.15	0.189	0.246	0.20

TABLE 4—Hinton Main Cleaning

Pipe Size	Ft. of Pipe Cleaned	No. of "Shots"	Max. Length "Shot"	Min. Length "Shot"	Ave. Length "Shot"	"C" Before Cleaning	"C" After Cleaning
10"	1,774	1	1,774'	1,774'	1,774'	—	128
8"	5,468	9	1,072'	215'	608'	48	126
6"	2,556	7	675'	189'	365'	80	117
4"	6,758	14	965'	36'	482'	44	122

TABLE 5—Sutton Main Cleaning

Item	Pipe 6" Main St.	Pipe 4" Town Hill	Pipe 4" South Side
Contract of Cleaning	$177.00	$325.40	$487.50
Material Cost	18.55	72.60	105.60
Labor Cost	90.50	166.40	249.20
Total Cost	285.85	564.40	842.30
Number of Feet Cleaned	1770	3254	4875
Cost per Foot	$ 0.161	$ 0.173	$ 0.172

TABLE 6—Sutton Main Cleaning

Location	Size	Ft. Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
Main Street	6"	1,770	42	136
Town Hill	4"	3,254	68	118
South Side	4"	4,875	71	117

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TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

TRANSITE PRESSURE PIPE . . . *a brief discussion of how this asbestos-cement pipe can help you provide more efficient water service at lower cost—*

A SUMMARY OF TRANSITE PIPE'S OUTSTANDING CHARACTERISTICS

●

MADE OF ASBESTOS AND CEMENT — Transite Pipe is built up under tremendous pressure on a polished steel mandrel to form a homogeneous structure of great strength and uniformity.

RESISTANT TO VIBRATION—By virtue of its flexible joints, Transite Pipe is resistant to the shock and vibration of traffic; authoritative reports from abroad indicate the ability of flexibly connected asbestos-cement pipe to withstand indirect bomb shock with little or no effect on the performance of the line. Simplex Couplings divide the line into a series of flexible links which relieve the line of high flexural stresses and which have been found to localize damage in the case of direct hits.

HIGH CARRYING CAPACITY — Because of its smooth interior, Transite Pipe provides an unusually high flow coefficient, C=140.

CANNOT TUBERCULATE — Because it is nonmetallic, Transite Pipe can never rust or tuberculate. As a result, delivery capacity can never be reduced by this internal corrosion — expensive cleaning to remove tubercules is never required.

HIGHLY RESISTANT TO CORROSION — One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is high resistance to corrosion — inside, outside and all the way through. Thousands of installations attest to Transite's durability in all kinds of soils.

TIGHT FLEXIBLE JOINTS—Composed of a Transite sleeve and two rubber rings, the Simplex Couplings used in Transite lines provide unusually tight, yet flexible joints.

WORKING PRESSURES—Transite Pipe is made in pressure classes of 50, 100, 150 and 200 for normal working pressures of 50, 100, 150 and 200 lbs. per sq. in.

EACH LENGTH RIGIDLY TESTED—Every length of Transite Pipe is individually tested to four times its specified rating in a hydrostatic test machine. In those sizes where flexural strength is important, each length of pipe is also subjected to a beam test.

SIZES—Transite Pipe is made in a wide range of sizes from 3-inch to 36-inch.

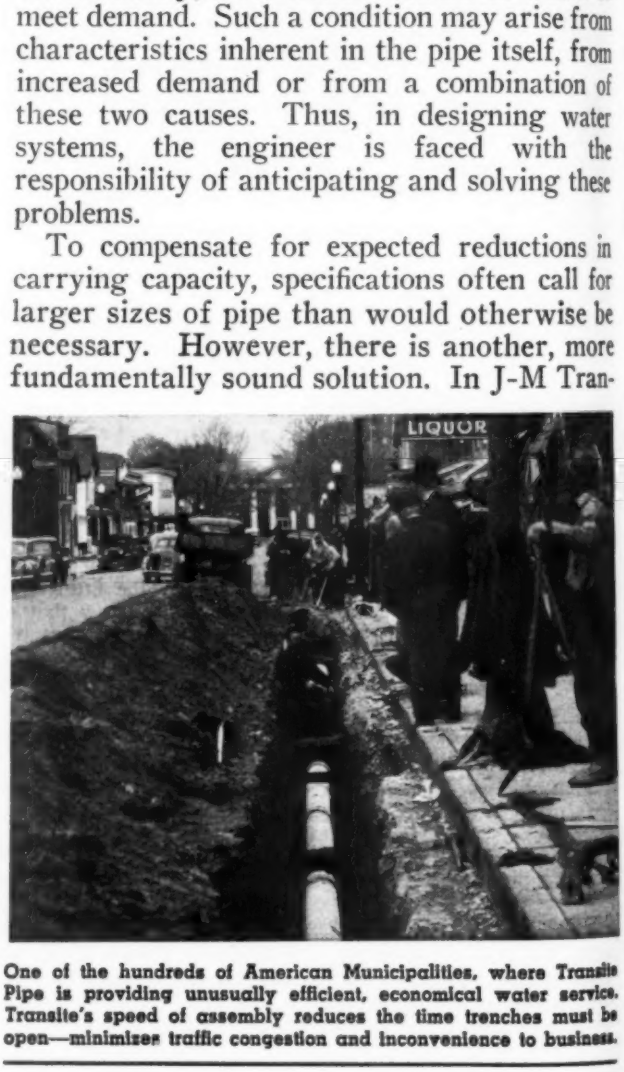
EASILY INSTALLED — Transite Pipe is furnished in long, 13-ft. lengths. Relatively light in weight, they are easily handled and installed. Simplex Couplings are assembled quickly and easily, even in wet trenches — a simple hydraulic coupling puller is the only tool required.

IN SELECTING a water pipe — whether for an extension or replacement of existing lines or the installation of a complete new system—careful consideration should be given to the basic factors contributing to the economic life of the pipe. For example:

DELIVERY CAPACITY . . .

Waterworks engineers generally agree that a water main, even though it remain structurally intact, may completely outlive its economic usefulness over a period of time. This point is reached when the pipe will no longer carry, economically, a sufficient volume of water to meet demand. Such a condition may arise from characteristics inherent in the pipe itself, from increased demand or from a combination of these two causes. Thus, in designing water systems, the engineer is faced with the responsibility of anticipating and solving these problems.

To compensate for expected reductions in carrying capacity, specifications often call for larger sizes of pipe than would otherwise be necessary. However, there is another, more fundamentally sound solution. In J-M Tran-



One of the hundreds of American Municipalities, where Transite Pipe is providing unusually efficient, economical water service. Transite's speed of assembly reduces the time trenches must be open—minimizes traffic congestion and inconvenience to business.

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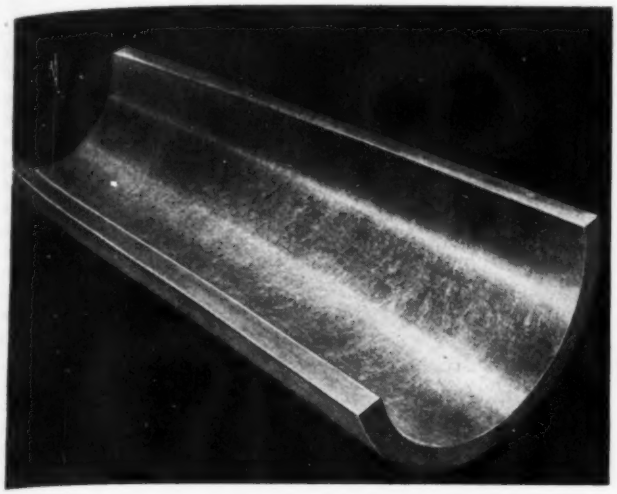


Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.

Over 62,000 feet of 10-inch to 30-inch Transite Pipe were used on this water collection and transmission system. Because of its light weight and speed of assembly, the pipe was laid as fast as the trench was opened.

site Pipe, engineers find basic advantages that permit them to specify the most economical pipe sizes with full assurance that delivery capacity will not be reduced by tuberculation, the internal corrosion which, even when present in relatively small degree, greatly reduces the carrying capacity of ordinary pipe.

Transite Pipe is an asbestos-cement product. During manufacture, it is built up on a polished steel mandrel that imparts unusual smoothness to the interior wall. Its flow coefficient is conservatively established at C = 140. This means that Transite water lines start with an exceptionally high carrying capacity.

Transite's freedom from tuberculation means that pumping costs stay low, for pressures need not be increased to compensate for a steadily decreasing flow coefficient and resulting loss of head in the line. Not only does this advantage provide worthwhile operating economies, but in many cases it also permits the use of smaller diameter pipe with resultant savings in all the numerous items that go to make up the original cost of completed water lines.

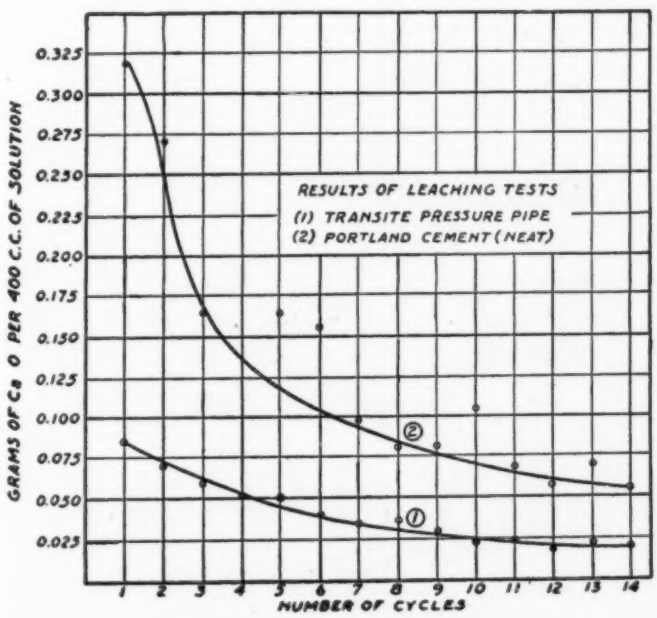
SOIL CORROSION . . .

Broadly speaking, most soil corrosion engineers agree that there are two principal forms of soil corrosion — chemical and electro-chemical.

Chemical corrosion is caused by the direct, corrosive action of acids and salts encountered in the soil. Transite Pipe, due to a special process of manufacture and treatment, is virtually inert to concentration of acids and salts ordinarily found in soils. Free lime which might generally be expected in cement products, has been largely converted to insoluble silicates due to the method of manufacture. A comparison of the two curves in the diagram below shows the high degree of insolubility of Johns-Manville Transite Pipe. It is for this reason that Transite is so highly resistant to all forms of chemical corrosion.

Electro-chemical corrosion is caused by the electrolytic action between ordinary pipe and materials in the soil. This action is similar to that of a simple electric cell. In this case, the materials in the soil represent the positive pole; the soil moisture, the electrolyte, and the pipe wall serves as the negative pole. The current generated passes from the pipe to the positive pole and causes a gradual disintegration of the pipe structure.

With Transite, however, this condition can never



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

JOHNS-MANVILLE

occur, because being non-metallic, Transite is a non-conductor—therefore absolutely free from electrical corrosion. Furthermore, this asbestos-cement pipe is immune to electrolysis caused by stray electric current from high voltage lines, streets, railways, etc.

The successful performance of Transite Pipe in all kinds of soil and under many varying climatic conditions provides practical proof of its high resistance to corrosion—inside, outside and all the way through.

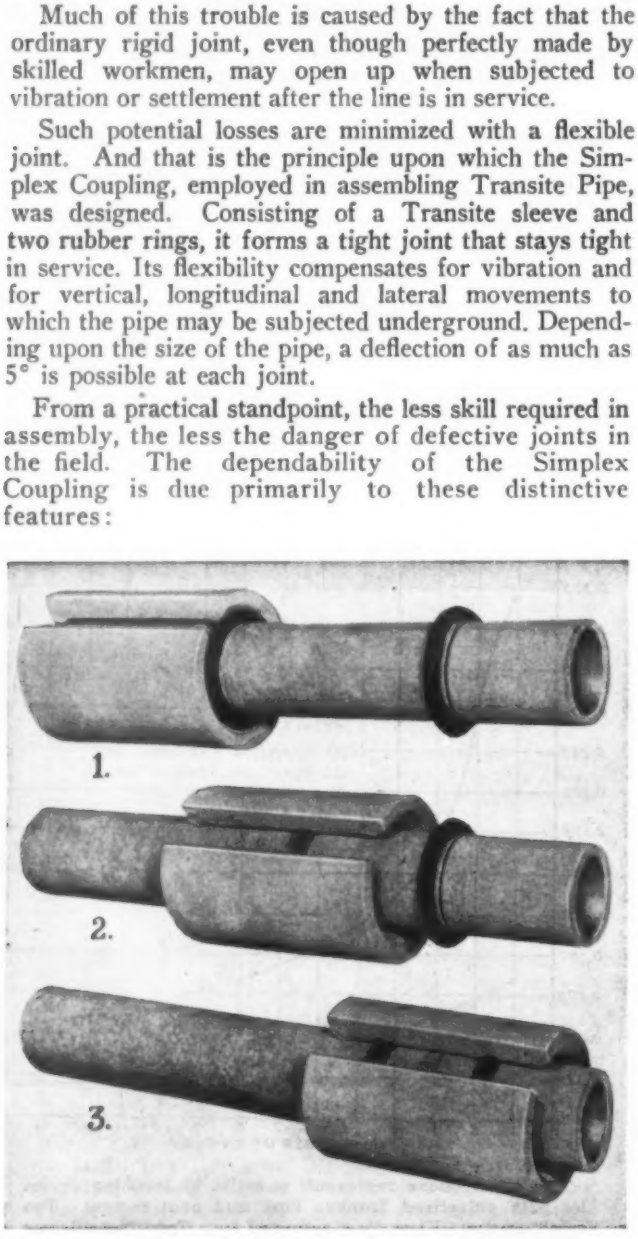
JOINT LEAKAGE . . .

Numerous surveys have shown that leaky joints are responsible for a considerable portion of total water losses from underground mains. Generally recognized by waterworks men as a serious problem, joint leakage not only results in a direct waste of water but, by washing away supporting soil, frequently causes pipe to fracture under traffic and earth loads.

Much of this trouble is caused by the fact that the ordinary rigid joint, even though perfectly made by skilled workmen, may open up when subjected to vibration or settlement after the line is in service.

Such potential losses are minimized with a flexible joint. And that is the principle upon which the Simplex Coupling, employed in assembling Transite Pipe, was designed. Consisting of a Transite sleeve and two rubber rings, it forms a tight joint that stays tight in service. Its flexibility compensates for vibration and for vertical, longitudinal and lateral movements to which the pipe may be subjected underground. Depending upon the size of the pipe, a deflection of as much as 5° is possible at each joint.

From a practical standpoint, the less skill required in assembly, the less the danger of defective joints in the field. The dependability of the Simplex Coupling is due primarily to these distinctive features:



Simplex Couplings Assembly (1) at start of operation (2) sleeve pulled over one ring, (3) final position, sleeve centered over joint.

With Simplex Couplings tightness of the joint can be determined from the outside as soon as the pipe is laid. A thin steel blade, slipped under the lip of the sleeve, checks the position of the rubber ring. If the position is right, the joint is tight.

1. It is actually a pre-fabricated, "packaged" joint. The ends of each pipe and the inside of each coupling are machined to specific dimensions. The rubber rings are precision-made and subjected to rigid inspection before shipment. Joints are assembled cold—no pouring, caulking or heating equipment is needed. A simple hydraulic coupling puller, loaned by Johns-Manville without charge, is the only tool required for assembly.

2. The effectiveness of the joint does not depend on the individual skill or training of the workmen. So simple is the operation that perfect Simplex joints can be made quickly and economically even by unskilled crews.

Made of Permanent Materials. The Transite sleeve, like the pipe itself, is made of asbestos and cement and has the same high degree of resistance to all forms of corrosion. The rings, made of the highest quality rubber, are carefully cured and specially compounded with anti-oxidents and properly graded non-hygroscopic fillers to assure permanence in water service.

INSTALLATION . . .

One of the major factors contributing to initial cost of a pipe line is the time and equipment required for installation.

Transite Pressure Pipe offers primary advantages that help speed up installation and cut costs. The long, 13-ft. lengths are relatively light in weight. Two or three men can easily lower 8 inch pipe into the trench by hand. In fact all but the very largest sizes can be handled without the use of mechanical equipment.

Simplex Couplings are assembled cold just as they are received from the factory. Wet trenches present no problem for no heating or caulking equipment is required. And the complete assembly is completed in much less time than required by ordinary types of joints.

WRITE FOR COMPLETE DETAILS

A detailed discussion of the economic factors contributing to efficient, low-cost water lines is given in the Transite Pressure Pipe Brochure, TR-11A. The 76-page "J-M Pipe Installation Manual," D. S. 332, outlines effective methods of installing water lines and includes much more data on Transite Pipe and the Simplex Coupling than was possible to include on these pages. For your free copy of these books, write to Johns-Manville, 22 East 40th Street, New York 16, N. Y.

JOHNS-MANVILLE

IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

Transite Sewer Pipe offers fundamental advantages that help reduce the cost of sewer line construction, maintenance and operation.

TRANSITE PRESSURE SEWER PIPE

Pressure Sewer Lines are very similar in operation to water lines and must meet the same general service requirements. In addition, the pipe must be highly resistant to the corrosive action of the sewage. Transite Pressure Sewer Pipe, which is made of the same durable asbestos-cement composition as Transite Water Pipe, described on the preceding pages, meets all these requirements and provides highly satisfactory service in systems of this type.

TRANSITE GRAVITY SEWER PIPE

Gravity Sewer Lines offer a number of specialized problems which Transite Gravity Sewer Pipe meets eminently well. For example:

INFILTRATION—

It has been authoritatively estimated that as much as 25% of the contents of the average sewer is ordinary ground water that enters the system by infiltration through the joints. And it costs practically as much to treat this water at the disposal plant as it does to treat sewage itself. Furthermore, in many cases, engineers must allow for this huge quantity of water by specifying a larger diameter pipe than would otherwise be necessary.

With Transite Sewer Pipe, however, the infiltration of ground water presents no serious problem. Transite's long 13-ft. lengths cut down the number of joints in the line, thus reducing the danger of infiltration right at the start. The poured sleeve joints employed in Transite lines are unusually tight and stay tight in service. The jointing compound is the highest quality, unfilled asphalt which, when set, provides a strong, flexible joint that is highly resistant to cracking or shrinkage. As a result, Transite Sewer Pipe lines have considerably less infiltration than that allowed by most specifications.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

CARRYING CAPACITY

One of the most important factors in any sewer line is carrying capacity. All other things being equal, the relative carrying capacity of two or more types of pipe is best indicated by their flow coefficient. If, for example, the inside of the pipe is rough and uneven, the flow velocity is low and carrying capacity is greatly reduced. A smooth pipe, however, has a high flow velocity and a correspondingly high carrying capacity.

Transite Sewer Pipe has an unusually smooth interior surface, its conservative friction coefficient when installed at the usual sewer pipe grade is N=.010. This high carrying capacity results in savings that can be taken in one of two ways. Flatter grades may be employed during installation — reducing the depth of the trench and making installation a faster, more economical job. Or, when the usual sewer pipe grade is maintained and deep trenches present no problem, Transite's high flow velocity often makes it possible to use a smaller diameter pipe without reducing the desired carrying capacity of the system.

OTHER CONSIDERATIONS

Resistance to corrosion, structural strength and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its asbestos-cement composition and its unusually low free lime content, Transite Sewer Pipe is highly resistant to the corrosive action of all types of domestic sewage and most industrial wastes—inside, outside and all the way through.

Transite Sewer Pipe is furnished in sizes from 4" to 36" in Class I, from 10" to 36" in Classes II and III and from 18" to 36" in Class IV. Each class of pipe is made to a specific crushing strength, thereby providing for the selection of the most economical combination of classes of pipe to meet the specific strength requirements of the line.

The long 13-ft. sections in which Transite is furnished eliminates many of the difficulties in installation common to ordinary short length sewer pipe. Relatively light in weight, these long lengths cut down handling costs. More footage may be carried per truck load to the trench and fewer men are needed to install the pipe. These long lengths also reduce the number of joints that must be made and thus save considerable time and labor. In addition, long lengths greatly facilitate laying the pipe to an accurate grade.

It will pay you to get further details about this modern sewer pipe. Brochure TR-21A presents them in brief, quickly read form. The "Transite Sewer Pipe Installation Manual" D.S. 342 gives valuable information and tabular data pertinent to installation problems. Write for these from Johns-Manville, 22 East 40th Street, New York 16, N. Y.

JOHNS MANVILLE JM PRODUCTS

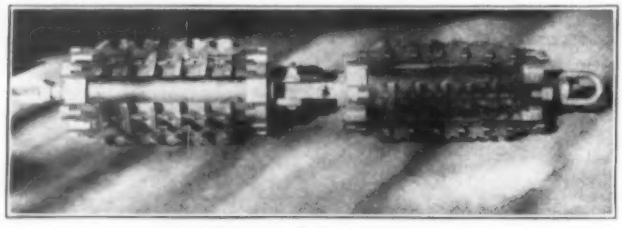
LINING CAST IRON MAINS IN PLACE WITH CEMENT MORTAR*

Experiences and Results at Charleston, S. C.

By JAMES E. GIBSON
Manager and Engineer, Water Dept., Charleston, S. C.

CEMENT-MORTAR lined and encased sheet iron and steel riveted water mains, and cement-mortar lined wrought-iron and steel service pipes have been in use in the United States, particularly in the New England States, for near unto one hundred years and are still giving good service. It was not until 1922, however, that the practice of cement-mortar lining of cast-iron water mains was introduced. The use of cement-lined and encased sheet iron water mains was more than likely dictated by the high cost of the cast-iron bell and spigot pipe of that time. The increasing demand and improvement in the manufacture, perfected by the pipe foundries, soon overcame the price differences in the two materials, so that by the late nineties the manufacture of cement-lined sheet steel pipe had almost ceased, the last company making this type of pipe being the American Pipe & Construction Co. of Philadelphia, Pa., with which company I was associated as assistant engineer to the late J. W. Ledoux, chief engineer.

Experience gained and flow tests made on cement-lined wrought-iron pipe as manufactured by this company, in comparison with tests on cast-iron mains of the same age laid in the same system and carrying the same water, showed the superiority of the cement-lined mains over the cast-iron mains. It was this experience that led me to propose to the commissioners of public works of the city of Charleston, S. C., in 1921, that standard cast-iron water mains could with profit be lined with cement mortar. We received favorable consideration from the pipe foundries to our suggestions, and in June, 1922, in cooperation with the American Cast Iron Pipe Co. of Birmingham, Ala., began experimenting with the lining of standard cast-iron pipe with cement mortar. During the fall of 1922 the Charleston Water Department laid some ten miles of cement-lined cast-iron pipe from 4-in. to 20-in. diameter.[1] Tests made immediately after laying this pipe in 1922, to determine the value of "C" (Williams' and Hazen's formula), gave values as high as 140 and averaged 135; and further tests within the last eighteen months show that these values have not depreciated, and in a few instances have improved. Based on observations, if the lining does not exceed ⅛-in. thickness, coefficients of 140 may be conservatively used for cement-lined cast-iron mains, even when based on the nominal diameter of the pipe.



Tate Self-Sharpening Cutting Scrapers
Elliptical Springs Hold Cutter Blades Against Pipe Walls

The cleaning of tuberculated cast-iron water mains has been practiced for the last thirty or forty years, but experience gained has shown that, with many soft active waters, cleaning must be repeated at varying intervals and thereby constitutes a recurring expense and an annoyance to the water consumers.

The executives of the Charleston Water Department, faced with their disappointing results from the cleaning of mains, and with their excellent experience with the cement-mortar lined mains, began to look for some practical method of protection of the exposed interior surface of the water main after cleaning.

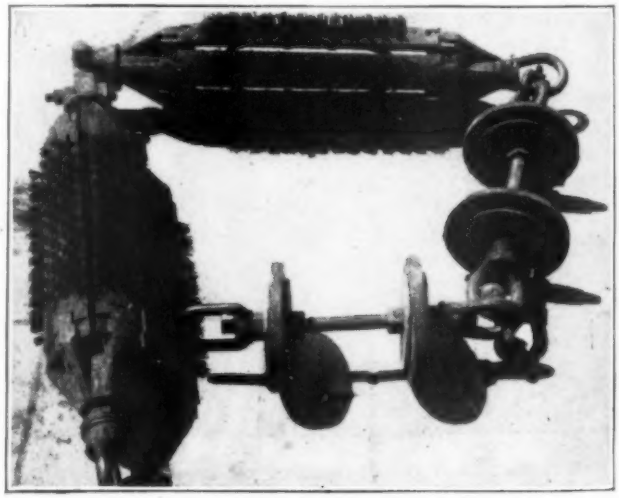
A Method Becomes Available

In about 1930, Mr. William Taren Tate of Sydney, Australia, began experiments with a process to cement-mortar line cast-iron mains in place, and in March, 1932, was granted Australian patents covering his process, and began the actual lining of mains in the Sydney Metropolitan Water Supply and Sewerage District. At the close of the year 1935 approximately 89 miles of mains had been lined in place and by the end of the year 1938 over 600 miles had been completed; and to date over 1,000 miles. In 1934, Mr. Tate demonstrated his process of lining mains in place to the Water Works Commission of Manchester, England. A description of the work done at Manchester was given in a paper by Mr. Thomas Wiggin, consulting engineer of New York City, presented before the American Water Works Association in 1935.[2] It was thus that our attention was directed to the Tate process of lining. The Tate Pipe Linings, Inc., of Andover, Mass., was incorporated Oct. 25, 1938, by Mr. E. H. Lewis of Andover, president, who obtained the license for the use of the Tate patents in the United States. Mr. Bruce Harkness of this latter company read a paper in February, 1939, before the New England Water Works Association,[3] giving his experience in lining water mains under the Tate patents, particularly in England and in Buenos Aires, Argentina. Later he took up with us the proposition of lining mains in Charleston, S. C.

As a result of the information gained from the above papers, and a study of the process and equipment as presented to us by Mr. Harkness, the Water Department of the City of Charleston entered into a contract in July, 1939, for a trial lining of about 2½ miles of 4-in., 6-in. and 8-in. water mains in the system. It is the work done under this contract that this paper describes.

Equipment and Procedure

The procedure of cleaning and lining is: First, the section of main to be cleaned is isolated from the rest of the system, and to take care of the consumers, if numerous, a small service main is laid along the gutter or curb in the street with outlets provided for each house service. This temporary service main is then connected to the water main at convenient locations, preferably back of valves in the section to be cleaned. If valves are not available then the main must be cut and plugged so as to take care of the feed to the temporary main without interference with the work. The street is then opened at all service connections and all services are disconnected. A section of rubber hose is inserted between the service pipe and the temporary main at the gutter, so that during the interval of cleaning and lining the consumers receive water through the temporary main and the flexible hose connecting it to their regular service lines. When there are only a few consumers on the main being lined, water can be supplied them through the use of large containers delivered by truck. Next, all hydrant leads, tees and cross-mains are disconnected from the section to be cleaned. The main at each end of the section to be cleaned (usually about 300 to 400 feet in length), is then cut so as to permit the introduction of the cleaning apparatus. By means of sewer rods or steel tape a cable is introduced through the section of main to be cleaned. This cable is attached to a single drum hoist mounted on a truck. At the other end a similar truck is employed so that the cable can be pulled back



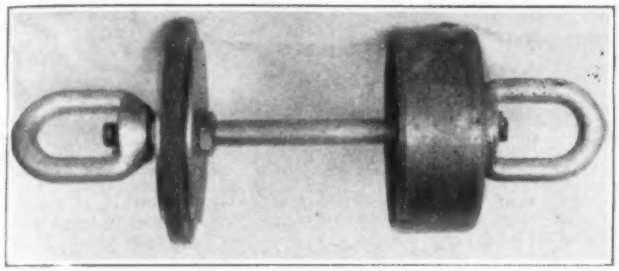
Wire Bristle Cleaning Brushes and Squeegees

*A paper read before the 60th Annual Convention of the American Water Works Association, and here printed by permission of the Association.

and forth alternately, each truck having a cable of sufficient length to pass through the section of main being lined.

The Scrapers

The cleaning equipment consists of cutting scrapers. These scrapers consist of a heavy wrought steel framework upon which are mounted cutter blades, the complete equipment consisting of two sections, the cutting blades in the two sections being staggered or rotated so that the trailing section cutter blades cover that part of the pipe wall not scraped by the leading blades. These blades are made up of heavy cast-steel sections mounted on a spider and held out to position by flat elliptical springs. Each section has three cutting blades for 4-in. pipe, and six cutting blades for 6-in. and 8-in. pipe. All cutting blades have six cutting edges, or knives. Blades are spaced symmetrically around the circumference of the spider and the knives are arranged in increasing diameter so that there is in effect a series of cuts made on the incrustations or tubercles on the walls of the main. The knives of the cutters are designed so as to be self-sharpening. The cuttings fall down through the spaces between the blades and with little exception most of this material



Metal Proving Plug Gives O.K. to Cleaning Job

is left in the main for subsequent removal. These scrapers are passed back and forth two or three times through the main being cleaned, depending upon the amount of incrustation or tubercles to be cut from the walls of the main.

Scrapers are of rugged construction and can readily remove any obstruction in the main such as overrun lead joints or protruding unchartered corporation stops, should such exist. (It might be well to note here that it is very important to have all corporation stops and services removed from the main in advance of the final lining operation, for if not they may cause the cement-lining to fall and form an obstruction in the main.)

Cleaning Brushes and Squeegees

After all adhering tubercles and foreign substance has been cut from the walls of the main, there is then passed through the main a series of scraper brushes made up similar to the scraper section except that the knives are replaced by sections of steel brushes. These steel brushes, built like heavy steel brushes used for cleaning steel plate for painting, are held in a manner similar to the cutter section described above.

Attached to the trailing end of the wire brushes are rubber squeegeeing pistons which are made up of steel plates with rubber discs inserted between the plates. These squeegeeing sections have a double function; first, they trail the wire brushes and force out ahead of them all of the material that has been cut loose by the scrapers and the wire brushes, so that the main is thoroughly cleaned of all loose foreign material. In like manner these brushes and rubber squeegeeing pistons are passed through the section three or more times, after which the brushes are removed, and the squeegees alone are passed through the main. This second operation is to remove all moisture, water, etc., that is lying in the main at low points, as the main must be entirely dry and free of all water. In our experience we found that after passing these squeegeeing pistons through the main, on the final exit the rubber was warm to the hand.

After this latter operation is completed, all corporation openings, crosses, tees, and outlets must be plugged with plugs that do not protrude into or through the walls of the main, but effectively close the opening. For fittings such as tees and crosses special plugs made slightly smaller in diameter than the bore of the pipe are inserted in the horn or the tee or cross and held in position by clamps. These plugs are made smaller in diameter than the bore of the pipe so that the lining mortar may be forced out around the plug and line the horn of the outlet. After squeegeeing the main for moisture, and before lining, the proper practice is to draw a proving plug through the main to make certain that there are no obstructions that will interfere with or injure the lining machine when it is put through. This proving plug is made of metal or wood that is slightly larger in diameter than the lining machine. It is probably more desirable to pass the proving plug by using man power, as the operator can thereby obtain a more sensitive survey of the condition of the main. The proving plug, having passed through satisfactorily, the main is now ready to be lined.

Mortar Preparation

Toward the end of the squeegeeing operation, a second gang of men is set to mixing the mortar for the lining. This mortar is composed of one cement and two sand, and is mixed in a steel mixing pan by hand, the procedure being, as in mixing any other mortar, first, to spread the sand out in an even layer over the bottom of the pan, to which is then added the proper quantity of cement, and then with square-nose shovels or billies the sand and cement are thoroughly mixed until an even color is obtained, after which the requisite quantity of water is added to give a satisfactory slump test.

It is important to have the mortar of proper consistency or slump and the amount of slump depends upon the size of the main being lined and the method used in introducing the mortar into the main. If introducing mechanically, a lower slump can be used than if introducing by hand. The company, organized in America, since its operations in Charleston and later at Falmouth, Mass., has developed a mechanical device for loading the cement-mortar into the main. This mechanical loader or charging device consists of a light, wrought-iron pipe connected to the end of the main and having a combination rubber and metal plunger attached to the cable used in cleaning. The cable is pulled up through the pipe so that the plunger is outside of the charging device; the vertical section pipe is then filled with the mortar, after which the plunger is placed in the pipe and pulled downward by means of the cable and the hoisting machine until the mortar is pulled down into the main. The plunger is then pulled back and a second charge of mortar introduced, and this is repeated until a sufficient quantity of mortar has been introduced to line the section of pipe cleaned. This is the more desirable method of introducing the mortar, for as above stated, you can have a lower slump test and less semi-laitance to be squeezed out of the mortar in the lining operation.

Lining Machine

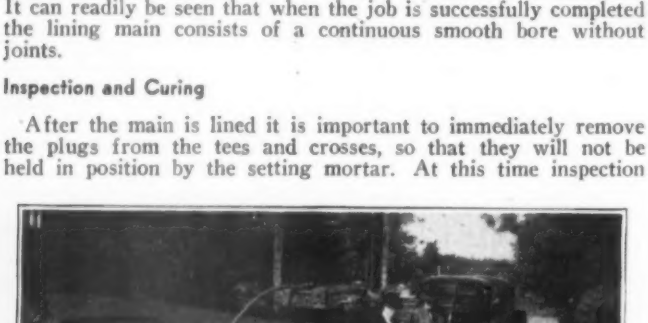
After a sufficient quantity of mortar has been introduced into the main, the loading device is disconnected and the lining machine is attached to the cable. This lining machine is a conical or bullet shaped device having a hollow steel frustum of a cone attached to the down-stream end, all mounted on a steel shaft or spindle. This leading or bullet section of the lining machine has two sets of four heavy elliptical cantilever springs set at 90 degrees to each other, which are slightly larger in diameter than the main being lined. The function of these springs, you will readily understand, is to hold the lining machine in the center of the pipe, so as to obtain a concentric lining in the main. The hollow skirt (conical section of the liner) is perforated with a large number of conical openings, bored from the inside, so that any material entering the openings from the outside, such as sand and cement, will free itself and not clog the openings. This is an important feature of the lining machine, as it is this portion that performs the function of dehydrating the cement-mortar, allowing the entrained air, excess water and the semi-laitance to pass through and be deposited gently on the bottom of the new lining. The last 1½ in. or 2 in. of the conical skirt of the lining machine is perfectly plain and smooth, and true to shape, and acts as a trowel to trowel out the mortar that has been plastered against the walls of the main by the pressure of the advancing head of the liner. As implied in the above, the function of the bullet and conical skirt of the lining machine is to force the mortar out against the walls of the main as the machine is being pulled through the main by the cable, the semi-laitance passing through the dehydrating openings and the smooth tail portion of the conical skirt acting as a trowel or float to smooth the interior surface of the mortar. It is important that the spindle upon which the bullet, springs, and perforated skirt-piece of the lining machine are mounted is straight and true in alignment.

There is always introduced into the main for lining a quantity of mortar in excess of that actually required. Some of it goes into the horns of any tees and crosses and fills the open spaces at the bell joints of the main. The average acts as a steadying plunger in front of the lining machine, so that the cable is always under tension and the lining machine under considerable pressure. Mr. Harkness tells me that tests made to determine the pressure immediately in advance of the skirt of the machine show that at times such pressure exceeds 150 pounds per square inch, depending, of course, upon the slump of the mortar, the volume of mortar in advance of the machine, the size and angle of the cone of the lining machine and the grade of main being lined. This, of course, makes for an extremely dense lining.

Over the outlet end of the pipe there is placed a canvas sheet or bag which is tied to the end of the pipe and is held close against the cable used for pulling the lining machine. The purpose of this bag is to create pressure on the excess mortar as it is extruded through the opening in the bag, thus assuring a continuous and uniform lining of mortar on the wall of the main. It can readily be seen that when the job is successfully completed the lining main consists of a continuous smooth bore without joints.

Inspection and Curing

After the main is lined it is important to immediately remove the plugs from the tees and crosses, so that they will not be held in position by the setting mortar. At this time inspection



Forced Feed Charging Riser
Note Cable and plunger which force into the main the charge of mortar placed in the riser.

by means of flashlights and mirrors is made of the interior of the pipe, particularly at the larger size openings, such as tees and crosses. Repairs, if needed, can at that time be made for any damage to lining due to the removal of plugs from fittings.

As soon as this inspection is made and everything is found satisfactory, all openings into the pipe, including the entrance and exit ends, should be covered with canvas bags so as to keep the air from circulating through the main, and to obtain the benefit of the heat of crystallization of the cement mortar in setting and the even temperature of the soil, thereby obtaining ideal conditions for curing. Usually within 15 to 20 hours the main can be restored to service, previous to which time the plugs used to close the tap openings at corporation stops may be removed and the section of lining covering these tap openings cut out with either a tool or a knife. In our work at Charleston we used a hand tool made from old combination drills and taps, by sharpening the drill end and inserting a tee handle on the shank end. We found these very efficient and the men could readily drill the cement-mortar out, and at the same time clean the thread in the tapped holes. The corporation stops may then be restored and the inlet and outlet entrances used for lining, closed by inserting a short section of lined pipe, using a solid sleeve. Then the main is filled with water and allowed to cure a further period of from ten to twelve hours. After curing with water for several hours the main is ready to be restored to service by blowing off the curing water through hydrant connections or service line.

For lining bends, off-set pipes and like fittings, the company has developed a special articulated short type lining machine.

Important Considerations

Important considerations in the process are: First, the thorough cleaning of the main, and as heretofore stated, the removal of all corporation stops and connections to the main being lined. Second, the quality of the sand and cement is important, as well as the dehydrating orifices in the skirt of the lining machine.

The preparation in advance of lining and the replacing of line into service, requires about ninety per cent of the total time, the actual lining requiring only a few minutes. Usually, depending upon conditions, about 800 feet of main can be lined in a working day of eight or ten hours, but in our work at Charleston, which was experimental, we did not make any such progress. We had distributed the work all over the city in an effort to get a comprehensive picture covering all conditions from ordinary dirt streets with few or no services, to congested residential sections where services averaged one every twenty-five feet, and under modern improved pavement, such as asphalt surface on concrete base.

The quality of the sand and cement used is very important, but of course it is desirable always, if possible, to purchase material that is obtainable locally in the market, and this was the procedure at Charleston. The cement used should have a reasonably long initial setting time. Pennsylvania Dixie Cement Corp. cement, used at Charleston, S. C., had the following characteristics:

Chemical Analysis:

Silica	22.10
Alumina	5.61
Iron Oxide	2.29
Lime	65.12
Magnesia	1.33
Sulphur Trioxide	1.50
Loss on Ignition	1.86
	99.81
Insoluble Residue	0.35

Compounds:

C_4AF	6.97
C_3A	10.97
C_2S	21.16
C_3S	54.62

Physical Properties:

Fineness ..... 93½% through a No. 200 Sieve
Specific Surface ..... 1,750 sq. centimeters per gram
Setting time, with Gilmore needle, initial 3 hours; final 5 hours
Tensile Strength: Proportion 1 to 3 Standard Ottawa sand briquettes:

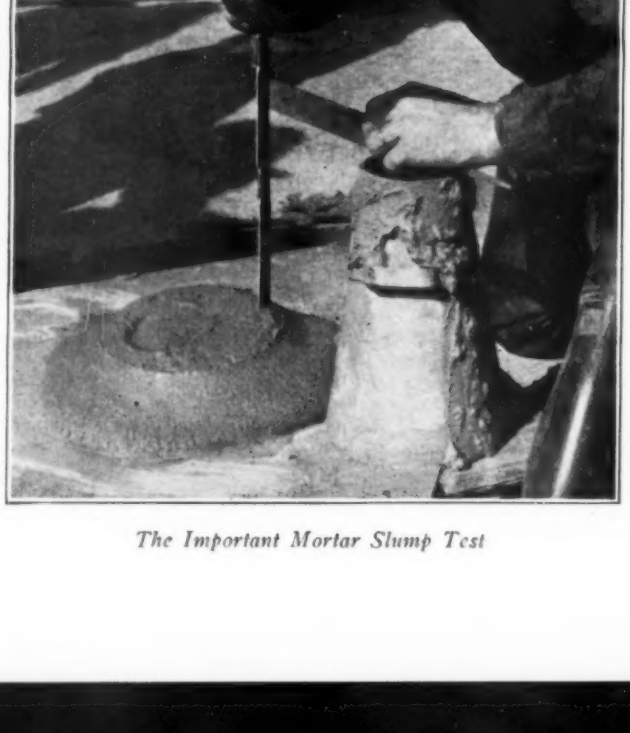
250 lb.— 3 days
340 lb.— 7 days
430 lb.— 28 days.

Cement was manufactured in every respect to meet the standard specifications for portland cement A.S.T.M., and Federal Specifications SS-C-191a.

The sand used was a sand obtained locally from what is known as the Saukehatchie pit, located near Yemassee, S. C. The grading test on this showed the following:

Retained	14	mesh	0.49%
"	28	"	10.58%
"	48	"	67.15%
"	100	"	17.58%
Passing	100	"	4.23%

The sand as received had the normal pit moisture and it was necessary to dry and screen it. On account of not being able to obtain proper screens we used No. 16 mesh galvanized window screening and rejected all material failing to pass this mesh screen. The sand, after drying and screening, was sacked, using one cubic foot to a sack, and hauled from storage bin to the job. The proportions of mortar used in lining were one to two and the slump test averaged from 7½ in. to 9 in., depending upon



The Important Mortar Slump Test

whether hand or mechanical means were used in charging the mortar into the main. The test of the mortar as mixed on one of the jobs is as follows. In this particular case the slump was 10 in., a little bit in excess of what was normally used for hand charging:

Tensile Strength—Pounds Per Square Inch

Time	As placed in the Pipe	Surplus cement mortar as extruded from the main lined
1 Day	175	180
3 Days	317	318
7 Days	417	467
28 Days	580	510

Curing for the first 24 hours in moist air, remainder of the time in water.

In our experimental work, it was our aim to place approximately ¼-in. thickness of lining in the main, but we were not at all times able to maintain this thickness, as we had a number of sections of pipe—one section of 8-in. pipe in particular—where we had ⅛-in. over nominal diameter to as low as ⅛-in. under nominal diameter, so we necessarily had to line this section with a lining machine not exceeding 7½-in. in diameter, which gave us a 3/16-in. minimum and a 5/16-in. maximum lining; but generally we obtained very close to ¼-in. thickness of lining. This is probably somewhat thicker than necessary, for we believe a 3/16-in. lining is just as good and probably as easy to obtain, provided, of course, you have a regular bore in the main to be lined.

The quantity of cement-mortar required to be introduced into the main varied with the diameter and averaged as follows for a section of 350 feet:

4-in main	105 feet
6-in. main	80 feet
8-in. main	60 feet

In all cases this quantity of mortar gave sufficient mortar to line the pipe completely, together with any connecting branches for hydrants, street crosses and tees, and an ample surplus extruded from the outlet end of the main.

Attainments and Results

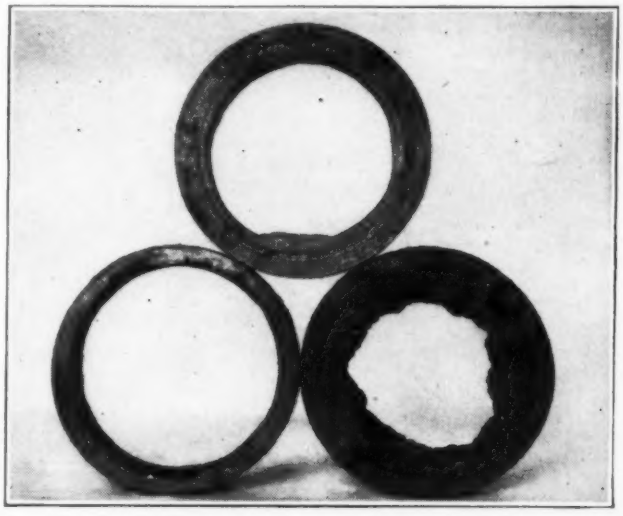
Statistical data as to location, diameter, and condition of the mains before cleaning, and after cleaning and lining, appears in an accompanying table. It will be noted that the value of "C" on nominal diameter of pipe was as low as 33 for a 4-in. main before lining, to a maximum of 128 on an 8-in. main after cleaning and lining. Expressed in per cent increased carrying capacity, the gains due to lining ran from 210 to 280 per cent. The age of pipe varied from twenty years to sixty years. Measurements to determine the value of "C" were based upon the actual measurement of water through a velocity type of meter, the piezometric head being measured with mercury or acetylene tetrabromide fluid in the U tube. The length of pipe involved in the tests varied from 172 feet to a maximum of 358 feet. All of these valves are based on the nominal diameter of the pipe, since we were not particularly interested in the academic question of such values based on the actual diameter of the cement-lined main. In one case, however, we did measure the diameter of the main after cleaning and determined the value of "C," which in this particular case was 140. This was a 4-in. pipe with actual inside diameter of 3.36 in. after lining, the reduction in area being 29.6 per cent. The actual discharge through the 4-in. main before lining was 130,700 gallons per 24 hours with a loss of head of 67.3 feet per 1000 feet of pipe. After cleaning and lining, with a loss of head of 66.8 feet per 1000 feet, the delivery per 24 hours was 316,400 gallons, or an increase in the delivery capacity of 240 per cent.

With the use of the hand charging and a high slump (9-in. to 10-in), there is considerable semi-laitance material squeezed through the dehydrating orifices so that there is a flat segment left in the bottom of the pipe. This material is of about the same nature as the mortar used in lining the pipe, but nevertheless this segmental area is objectionable to the extent that it does reduce the area of the pipe, and the desirable condition would be to reduce it to the irreducible minimum. To accomplish this, it is desirable to use as low a slump test as possible, and this requires the use of a mechanical charging device.

Costs

The cost of the work ran from about ¼ to ½ the cost of replacement of the main, and of course varied with the kind of paving, number of services, hydrant and street crossing connections. It can be readily seen that the cost of cleaning and lining 8-in. main is relatively much cheaper per foot than the 4-in. or 6-in. main as the cost of opening up the paving in the street for introducing the cleaning scrapers, cement-mortar and lining machine, service, hydrant, and street crossing connections, is practically the same without regard to the size of the main lined. The time of cleaning and lining is relatively the same, and therefore the only increased cost in lining 8-in. main over 4-in. and 6-in. main is the cost of the material required and the cost of the larger equipment. Actually in our trial projects at Charleston, based upon the condition under which the work was done, the cost of the work was as follows:

	Per ft.
4-in. main:	
Sand asphalt penetration pavement, with taps averaging one about every 60 feet	$0.55
Unpaved street, with few services, little traffic, this cost dropped to	.45
6-in. main:	
Paved territory, asphalt concrete base, services averaging every 30 feet apart	.90
Open territory, unpaved streets	.46



Sections of 6-Inch Main Before and After

Note the lined section at the top, showing the bottom segment of semi-laitance which should be kept to a minimum.

8-in. main:	
Paved street, asphalt concrete base, with services averaging every 60 feet	1.55
Unpaved streets, minimum number of services	.50

These costs included the cost of opening up the street and replacing the paving in every case, and in residential sections where there were numerous services, the installation of a 2-in. galvanized main at the curb, with connections to receive water at each end, and the connection of the service pipes to this temporary main. It does not include any cost for the material used in making these temporary connections, and the figures given in this tabulation are averaged for the work. The maximum, at times, went to probably 50 per cent above these averages. This, however, was an exceptional case where the main was sixty years old, and was very much deteriorated due to the soil corrosion; and the further fact was that it was a very thin cross-section, walls being less than ⅜-in. thick in places. The average depth of the main was 36-in. cover.

Conclusions

Attainments from our trial projects in Charleston have been very satisfactory indeed, and we have no hesitancy in saying that we will do additional lining as soon as we can, and financial conditions allow it. We have received very complimentary remarks from the consumers along the lines which we have lined in that the volume of the water has been increased and they do not suffer from the periodic disturbances and roily water as formerly when excessive drafts occurred.

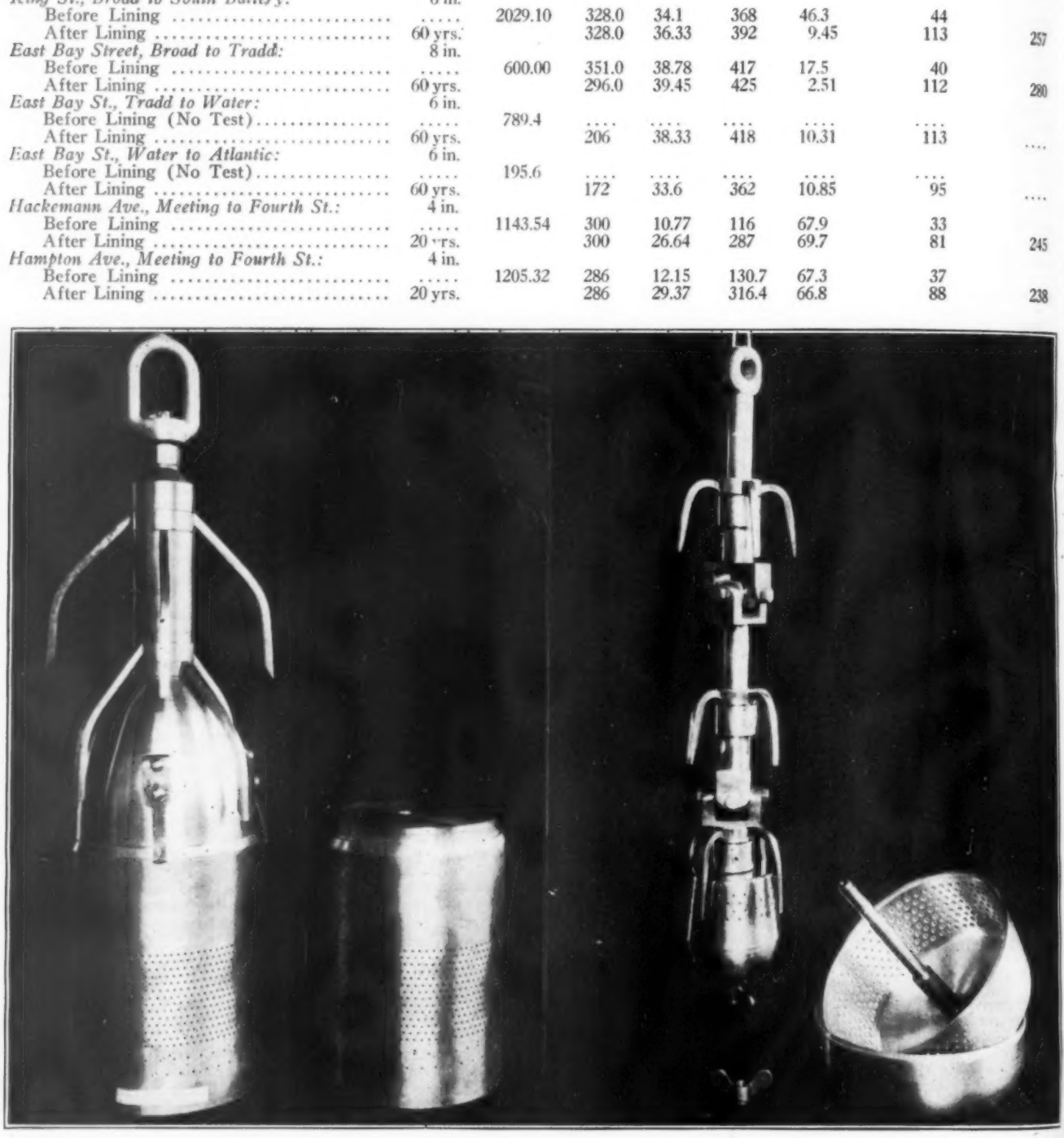
Some Pertinent Considerations

To reduce the segment of material passing through the dehydrating orifices of the lining machine it is desirable to maintain as low a mortar slump test as possible. To that extent we feel that the introduction of some plastercizing material such as Celite, Duracrete, or even hydrated lime, would be desirable in that it would give a more plastic and buttery mass than the straight Portland cement and sand. The introduction of this inert material would probably slightly reduce the strength of the mortar on a tensile test but as we see the picture this is

Tabulation of Information and Results

Lining 4-inch, 6-inch, and 8-inch Cast Iron Mains in Place by Tate Linings, Inc., of Andover, Mass.
(Age of Pipe 20 to 60 Years—Total Feet 12,009)

	Nominal Diameter Age of Pipe	Lin. Ft. of Pipe Lined	Lin. Ft. of Pipe Tested	Flow Cu Ft. per Minute	1000 Gallons per 24 Hrs.	Loss of Head per 1000 ft. of Pipe	Average Value of "C" Nominal Diameter Hazen & Williams Formula	Per Cent of Improvement
Durant Ave., North Charleston:	8 in.							
Before Lining	.....	3450.50	358	32.47	350	7.1	53	
After Lining	27 yrs.		358	32.63	351	1.77	112	210
Charlotte St., Washington to Concord:	8 in.							
Before Lining	.....	652.70	257	43.26	466	12.9	51	
After Lining	29 yrs.		257	41.28	445	2.125	128	251
Prioleau St., Tradd to S. C. Yacht Club:	6 in.							
Before Lining	.....	688.00	244.7	40.52	436	81.4	39	
After Lining	60 yrs.		303.0	36.40	392	12.0	98	251
Legare St., Tradd to South Battery:	6 in.							
Before Lining	.....	1255.00	271.0	34.17	368	37.35	50	
After Lining	60 yrs.		271.0	35.18	379	8.33	117	234
King St., Broad to South Battery:	6 in.							
Before Lining	.....	2029.10	328.0	34.1	368	46.3	44	
After Lining	60 yrs.		328.0	36.33	392	9.45	113	257
East Bay Street, Broad to Tradd:	8 in.							
Before Lining	.....	600.00	351.0	38.78	417	17.5	40	
After Lining	60 yrs.		296.0	39.45	425	2.51	112	280
East Bay St., Tradd to Water:	6 in.							
Before Lining (No Test)	.....	789.4	....	....	....	....	....	
After Lining	60 yrs.		206	38.33	418	10.31	113	....
East Bay St., Water to Atlantic:	6 in.							
Before Lining (No Test)	.....	195.6	....	....	....	....	....	
After Lining	60 yrs.		172	33.6	362	10.85	95	....
Hackemann Ave., Meeting to Fourth St.:	4 in.							
Before Lining	.....	1143.54	300	10.77	116	67.9	33	
After Lining	20 yrs.		300	26.64	287	69.7	81	245
Hampton Ave., Meeting to Fourth St.:	4 in.							
Before Lining	.....	1205.32	286	12.15	130.7	67.3	37	
After Lining	20 yrs.		286	29.37	316.4	66.8	88	238



Tate Lining Machines
(Left) Machine for straight-away pipe lining. (Right) Articulated machine for bends or crooked lines

immaterial as long as the mortar has sufficient strength, cohesion, and stability to adhere and maintain the arch in the main. Our experiments show that by the use of such plastercizing material a very much reduced slump test can be had.

Use of Graded or Kiln-Dried Sand

To obtain the best results, we believe it would be advisable to pay considerably more attention to the grading of the sand, even to the extent of having it kiln-dried and graded. Since completing the Charleston work, this was demonstrated conclusively, I think, in the work done by Tate Pipe Linings, Inc., at Falmouth, Mass. In that project, kiln dried and graded sand, put up by the material contractor in cubic-foot sacks, was used. Analysis of that sand, as furnished by the Tate people, is as follows:

Mesh	*Percentage Retained*
10	0.5
20	10
30	35
40	16
50	26
80	5
100	7
200	0.5

The advantages of using kiln-dried and graded sand are that you can better control cement-water ratio and obtain the grade of aggregate that you desire; and, since the sand cost is such a small percentage of the total cost, the additional expense of kiln drying and grading is not of moment.

Necessity of Lining

A survey[4] of water supply facilities of the United States, 1939, shows that there are 12,760 water works plants in the United States, serving 13,293 communities. Of the total number of water supply systems, 8483 obtain water from either driven, bored, or shallow dug wells, springs or infiltration galleries; and 3123 from surface supplies such as streams and lakes. There are 2188 systems having filter plants.

It has been recognized for a number of years that the process of treating and filtering water disturbs the chemical balance of the water, making it more aggressive. Filtration engineers and chemists have corrected this to a great extent by treatment, but there is evidence that tuberculation is not always completely checked by such treatment. Estimate of the mileage of mains, based upon the 1930 census and the known mileage of mains in some fifty-three cities and urban communities, brought up to July, 1939, indicates that there are in continental United States not less than 224,000 miles of cast-iron water mains 4 in. and above in size. We estimate that at least 90 per cent, or 200,000 miles, are from 4 in. to 12 in. in diameter, so it can readily be seen that with the known active or aggressive waters throughout the country there is a large field and necessity for the restoration of carrying capacity of the mains now laid and in service. The reconditioning of these water mains in place means that their functional life will be increased from a few years to probably as many as fifty years, depending upon their present age. The process should effect a considerable economic saving to water companies and municipalities throughout the United States.

Permanency of Lining

There has been considerable discussion among engineers and chemists as to the permanency of cement-mortar lining, particularly due to the leaching or dissolving out of the calcium content of the cement, destroying the stability of the mortar. Time, which is the test of all material things, indicates that this deterioration is much like Mark Twain's death, "very greatly exaggerated," for we have records of cement-mortar lined water mains and service pipe laid in New England, sixty years of age or older, that are still in service and going strong.

Size of Mains That Can Be Tate Lined

Representatives of the Tate company tell me that the largest main that they have yet lined in the shop is 15-in.; and I can see no reason why in-place lining cannot be carried out successfully up to 12-in. diameter pipe. The difficulty of lining larger mains by the Tate process, as we see it, is maintaining a satisfactory plug or volume of cement mortar to fill the cross-section of the main in advance of the lining machine. We understand, now, that a type of dam or baffle has been devised to maintain the desired mortar plug under compression ahead of the lining machine.

There are, so far as we are aware, only two companies attempting to recondition or line mains in position. They are the Tate Pipe Linings, Inc., of Andover, Mass., for mains from 6 to 12 in. in diameter, and the Centriline Corp. of New York, a new company that has just recently been organized by T. A. Gillespie, the Lock Joint Pipe Co. and the Raymond Concrete Pile Co., who have taken over the patents of the Perkins process for lining steel and cast-iron mains of large diameter with cement-mortar. This work has formerly been done by the T. A. Gillespie Co.

References

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2. Proceedings of the American Water Works Association. Vol. 27, No. 8, page 1073, August, 1935. "Applying Cement Mortar Lining to Existing Mains in England."
3. Proceedings of the New England Water Works Association, Vol. 53, No. 3, page 284, September, 1939. "Cleaning and Lining Existing Pipe Lines in Buenos Aires."
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DETERMINING COST OF PUMPING WATER*

Frequently it is desirable to determine the cost of pumping water within reasonably close limits. The following formulas will give the approximate cost of operation per hour for any given condition, based upon the cost per kilowatt hour, per gallon of fuel or cubic foot of gas.

(1) Electric Power—

$$\text{Cost per hour of operation} = \frac{\text{GPM} \times \text{Total Dynamic Head in Feet} \times .746 \times \text{rate per KWHr.}}{3960 \times \text{Overall Pump Efficiency} \times \text{Motor Efficiency}}$$

For example assume 1,000 GPM, 80-foot total dynamic head, 70% Overall Pump Efficiency, 90% Motor Efficiency and cost of 2c per KWHr.

$$\frac{1000 \times 80 \times .746 \times .02}{3960 \times .70 \times .90} = 47.84\text{c per hour}$$

(2) Diesel Engines (based upon an average fuel requirement of .065 gallons of Diesel fuel per HP Hour).

$$\text{Cost per hour of operation} = \frac{\text{GPM} \times \text{Total Dynamic Head in Feet} \times .065 \times \text{Cost of fuel per gal.}}{3960 \times \text{Overall Pump Efficiency}}$$

For example assume 1,000 GPM, 80-foot total dynamic head, 70% Overall Pump Efficiency and cost of fuel at 8c per gallon.

$$\frac{1000 \times 80 \times .065 \times .08}{3960 \times .70} = 15\text{c per hour}$$

(3) Gasoline Engines (based upon an average fuel requirement of .110 gallons of gasoline per horsepower hour).

$$\text{Cost per hour of operation} = \frac{\text{GPM} \times \text{Total Dynamic Head in Feet} \times .110 \times \text{Cost of fuel per gal.}}{3960 \times \text{Overall Pump Efficiency}}$$

For example assume 1,000 GPM, 80-foot total Dynamic Head, 70% Overall Pump Efficiency and cost of gasoline at 20c per gallon.

$$\frac{1000 \times 80 \times .110 \times .20}{3960 \times .70} = 63\text{c per hour}$$

The above formulas give the approximate operating costs per hour without taking into consideration the initial cost of the plant, maintenance or man-hour cost of operating the plant.

*Reprinted from Layne and Bowler's Pump Bulletin 4-42.

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

VALVES, HYDRANTS AND WATER WORKS ACCESSORIES

Efficient domestic water systems, sanitary sewage systems, and fire protection for municipalities involve a great number of control valves and hydrants. M & H products with their record of high quality, rugged strength and dependability can safely be recommended.

The Mark of Quality

M & H FIRE HYDRANTS

Conform to latest A.W.W.A. specifications. Simple, rugged design minimizes maintenance costs. Features are:

1. Dry Top—Operating threads protected from action of water. No rust, corrosion or freezing.
2. Easy Lubrication of operating nut, threads and packing through lubricating screw in top of operating nut.
3. Revolving Head, outlets faced in any direction.
4. Addition of Steamer Nozzle, without digging up hydrant or requiring complete new barrel.
5. Lengthening of Hydrant without digging up or requiring complete new barrel.
6. Double Lead Gaskets on Bronze valve seat.
7. Removal of Bronze Seat, or any working part, without digging up Hydrant.
8. Double Drain Valves, absolutely positive, insuring quick and complete draining of Hydrant.
9. Lugs on Bell of Hydrant Shoe for strapping to the water main, if desired.
10. Compression Type. Water pressure keeps valve tight.

SPECIAL TRAFFIC MODEL FIRE HYDRANT

Equipped with cast iron bolts and breakable coupling on the stem. Breakage due to traffic collision is limited to these cast iron parts which are easily and quickly replaced without shutting off the pressure.

M & H A.W.W.A. GATE VALVES

Iron body, bronze mounted gate valves are furnished in the double disc parallel seat or solid wedge types with non-rising stem, outside screw and yoke, or with sliding stem and lever. Supplied to fit any standardized pipe connections. By-pass valves can be furnished, unless otherwise specified, in sizes according to A.W.W.A. specifications.

SPECIAL TYPES

Hydraulically Operated: for remote control of operation and for quicker, easier opening or closing. Can be supplied in any of the standard sizes of M & H A.W.W.A. gate valves, either high or low pressure.

M & H Square Bottom Gate Valves: specially designed for operation in any position. Particularly recommended for use in intake towers or at the foot of dams; for pressure regulation by throttling the flow of water in centrifugal pump discharge lines; for regulation of flow in feed line to a filter bed; and for flow regulation from a reservoir where there is unbalanced pressure against the gates.

PRESSURE CLASSIFICATION—2″ TO 30″ SIZES

Class	Working Pressure	Hydrostatic Test
AA	0 - 25 lb.	50 lb.
A	26 - 50 lb.	100 lb.
B	51 - 100 lb.	200 lb.
C	101 - 200 lb.	350 lb.

CHECK VALVES

For intsallation in horizontal or vertical position. Can be supplied with by-passes. May be furnished with an outside lever and weight. Sizes from 2″ to 12″ for working pressure up to 200 lbs.

OTHER PRODUCTS

Tapping Valves
Mud Valves
Shear Gates
Flap Valves
Wall Castings
Floor Stands
Flanged Fittings
Flange and Flare Fittings
B & S Fittings
Cutting-In Tees
Valve Boxes
Special Castings

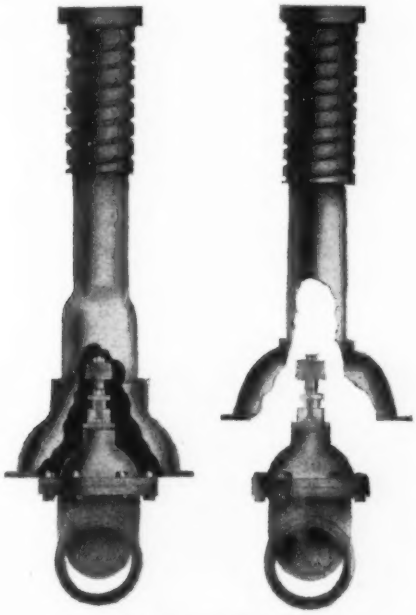
GATE VALVE CARE AND MAINTENANCE

By ROGER W. ESTY

Superintendent, Water and Sewer Board, Danvers, Mass.

TOO commonly, one of the most neglected of the routine operations in a water works system is the care and maintenance of gate valves. In some of the larger cities there are maintenance crews created particularly for this type of work. The crew is generally made up of some of the older men who are experienced in this work, due to their long service with the department or the water company.

They are furnished with a truck equipped with all the necessary tools, wrenches and spare parts, and they may also have built into the truck a mechanical operating device to open and close the gate valves. Smaller towns are more often than not unable to give proper attention to their gates, due primarily to lack of sufficient man-power to do this work and carry on the many other essential activities common to a water works plant.



Valve Box Settings

On the left is a setting as it is pictured in catalogs, and generally installed. To my way of thinking, the method of putting the valve nut-up in the contracted section is improper. On the right is a suggested better way for the several reasons cited in the text. Possibly this may suggest an advantage to be gained in an improved design of this type of box to give better overall service.

My water works experience goes back over a period of 27 years. During that time I have located, measured and plotted onto cards and maps every hydrant, gate valve, and all of the pipe in our system. I have opened and closed every gate valve many times. It was 20 years ago that we first had a water waste survey made of our system and, as many know, this necessitates the opening and closing of essentially every gate valve in the system. This type of work we have continued every second year since, which affords added opportunities of locating and operating all of our gate valves.

Main Flushing Reveals Gate Valve Conditions

Occasionally our piping system is entirely flushed out, street by street, and this again means the operating of nearly every gate valve, and some have to be opened and closed several times during this flushing operation if properly conducted.

From this work experience is gained in the knowledge of what to expect of gate valves and the remedies that are used in perfecting their operation.

Stiff Operation a Main Trouble

One of the main difficulties, if not the main difficulty, we find with gate valves is that they turn hard. As years go on, if such valves are not operated occasionally they become more difficult to operate and in some cities and towns it takes two men, or even as many as four and six men, to close down a gate valve even during a testing period.

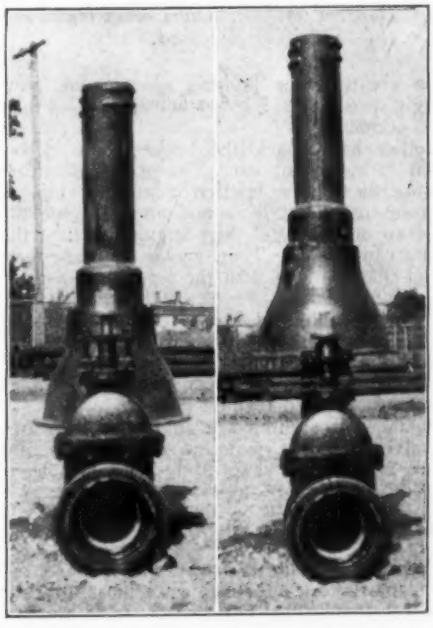
My experience does not go beyond a 20-inch gate valve, but it seems to me that the same principles and characteristics are applicable to all sizes.

A great deal of the indifference toward gate maintenance can be traced to the swivel chair operator. By that I mean the man in charge of the water works who has never experienced the opening and closing of all of the gate valves in his system. If he made tests of his system, such as a water waste survey, and had to work all night opening and closing these gate valves himself, he would soon issue an order to do something about making them operate easier. But generally, it is below his dignity to leave his swivel chair to do this type of work, to find out first hand the physical condition of his system. He doesn't care; he doesn't have to operate them; let the men do it, even if it does take two, four or six to do the job.

The Remedy

What are the difficulties we encounter; what causes them, and how can they be remedied? Why should it take four men to close a gate valve when one man should do it?

Why do stems get bent and broken? What is the cause of all this? Is it because the mechanism is not correct in design, or that the mechanism is not made heavy enough? I feel that the manufacturers as a general rule put on the market a gate valve that will meet all reasonable conditions according to our water works standard specifications. However, I do think the manufacturers do lose sight of one very important factor, and that factor is the packing, and in my opinion, if improper or



A photographic attempt to indicate the advantage of setting the box bonnet higher, giving more clearance between box walls and nut and stem of the valve. The usual setting (left) is in truth a "rock trap," while the other permits rocks to pass by; also makes for easier key connection with the nut should the box become off-center.

neglected packing is not the direct cause, it is at least the seat of 90 per cent of all gate valve troubles.

Many ask, why does the packing have such an important bearing on the ease of operation of the gate valve? Well, the packing gets dry and hard as the years go on. This dry packing acts as a brake on the valve stem.

Take, for instance, your automobile—the brake linings are dry and the brake drum of the wheel is smooth and dry. When the pressure is exerted against one another it creates friction, and

Danvers' Alemite Lubricating Outfit Servicing a Geared Valve.

this friction creates your braking or stopping power. Sometimes at high speeds this friction actually locks the wheels and causes fatal accidents.

On the other hand, pack the brake drums with grease and then attempt to stop your car. The grease eliminates the friction, therefore there is no friction created to stop your car.

Take a rope and wind it around an inch pipe three or four times and draw it tight and then attempt to turn the pipe. You will find you can't do it. Then grease the rope thoroughly and you will find that you can turn the pipe very easily. Try it for your own satisfaction.

Did you ever try holding an eel in your hand? If you have, you probably found that it was nearly impossible to hold it because it was so slippery. If you can get your gate valve stem and packing in the slippery condition you find the eel, you'll have no more hard turning gate valves.

However, there is a difference in the mechanism in some of the gate valves and one make may operate a little different than another make when new. But on the whole, modern gate valves should operate more or less in the same easy manner.

A Case of Proof

Several years ago, while making a water waste survey during nights, we came across a 12-inch gate most difficult to operate. It took the combined efforts of two of us to open and close the gate. The next day I had the gate dug up and repacked. It seems hardly believable, but it could then be turned with just one finger against the cross-bar of the gate key.

Such ease of operation surely saves breaking or bending the valve stems and makes the operation of the gate a pleasure instead of a dreaded job.

Some Packing Pointers

On many of our gate valves and nearly all of our hydrants we have removed the original braided packing and inserted a metallic plastic packing, with two or three strands of flax string type packing on top to keep it from squeezing out when the packing gland is tightened down.

After taking out all of the braided packing, we squirt down around the stem near the packing plate some kerosene or light lubricating oil. We then fill up the stuffing box with a metallic packing that comes in a loose plastic form or in string form. We then put on the stuffing box follower and tighten it down. We then open and close the valve a few turns and then tighten it some more. If it needs a little more packing we insert some and go through the operation again. This method has solved our packing problems and made hard turning gate valves easy turning, and makes fun out of a disagreeable job.

The Larger Valves

In the large gates we drill a hole through the packing plate and insert an alemite fitting. These gate valves still have the braided packing in the packing box. By connecting a grease gun to this fitting we can apply by means of our air compressor about 3,500 pounds pressure and this forces the grease in and around the stem and packing and does a very satisfactory job of lubricating.

It does such a good job on these gate valves that it is a monotonous one man job of opening and closing the valve when testing; in fact, a boy 10 years old can operate the valve.

Large gate valves should have an ample size manhole constructed around them so that a man can get down to the gate and repack it. Smaller gates can be handled more economically by using a 5¼ or 7-inch valve box over the gate with the cover flush with the road.

The gears of a geared gate should be enclosed in a housing with the gears running in oil. If the gears are not housed then they will collect rust and dirt in between the gears or teeth,

Danvers' Method of Marking Street Gate Locations.
Yellow figures stenciled on black field on nearest pole.

making them fit tight and bind, causing the gate to operate hard. Dirt falling down into the hole when the cover is picked up causes some of this trouble.

We have eleven 20-inch open geared gates and we wish we had purchased the oil enclosed style. That surely was an error on our part, but our experience with them has taught us to advise others to buy the oil enclosed style.

We have constructed a shield that fits over the gears and the operating nut and fastens to the bolts holding the stuffing box to the bonnet of the gate. This has proved very satisfactory and the dirt does not get into the gears. This gives us the opportunity to keep them well greased.

Improper Valve Box Setting

Many gate valve catalogues show what, in my opinion and experience, is an improper method of setting the box over the gate. Pick up any catalogue and turn to the gate box section

showing the 5¼ or 7-inch box. You will notice that the base or pot sets down over the top of the gate so that the base of the box is even with the flange in the center of the gate. Then the upper section, or middle section, is set onto the base, leaving the operating nut up in this section.

My contention of it being an improper setting and causing maintenance troubles is that if rocks do get into the boxes (and the kids sure do put them in sometimes), that the rock cannot go down past the operating nut. It gets wedged in so hard sometimes that it is impossible to get the key onto the operating nut, and if you do, you cannot turn it. If the box is pushed to one side slightly, the box then comes up against the operating nut and prevents putting the gate key onto the operating nut.

If, on the other hand, the base or pot is set so that the base is up at the level of the stuffing box plate, rocks then can roll to one side into the base, and if the box is tipped there is a greater possibility of getting the gate key onto the operating nut.

In my opinion, box setting is a very important part of your gate maintenance work.

Location Records

Location plans of gate valves should be carefully prepared and measurements should be taken from permanent benches, such as to other gate valves, hydrants, catch basin grates, manhole covers, curbs, etc., and not from telephone poles, trees, walls, fences, etc.

These measurements should be on cards and on sheets in bound books for quick reference. Each should have a number and these can be painted on the underneath side of the valve box cover if desired.

Stencilling of measurements onto buildings, poles, etc., are helpful for quick locating. Numbers can be nailed onto poles or buildings that will stay on as long as the pole or building remains in place. We paint a black square on the reference object and nail on the metal numbers that have been sprayed with an orange colored paint. The contrast makes it conspicuous from any other type of marking.

Removing Recalcitrant Box Covers

Sometimes the gate box cover gets sealed in with tar, or in the winter is frozen in. This can be very easily overcome by pouring a little gasoline on it and setting it on fire. In a few moments the cover can be easily removed.

Quite often it is found difficult to close the gate tightly. This is generally caused by tuberculation in the valve guides and seat. By opening and closing several times this incrustation breaks off and the velocity of the water between the gate and the seat of the valve will most always flush out, allowing the gates to eventually properly seat and closing off entirely the flow of water.

Gate valve work is not expensive. It is a tedious job but can be made very interesting by the various things that have to be done, such as checking measurements, marking poles or buildings, opening and closing, repacking, and the resetting of the gate box at higher elevation.

If a few of these suggestions are followed, most of your gate valve worries will be a thing of the past:

Good plans and measurements.

Stencilled or metallic reference numbers on poles, buildings, etc.

Gate box covers flush with the surface of the ground.

The base of the box well above the center flange of the valve.

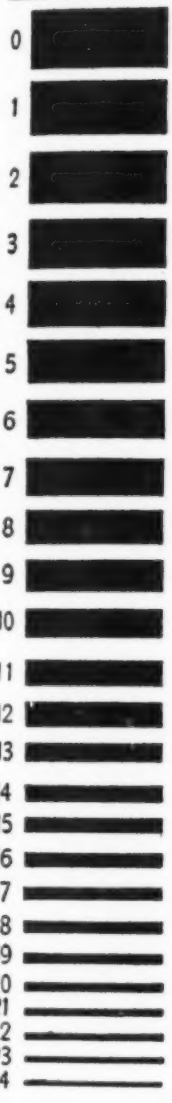
Opening and closing each valve on a yearly schedule.

Last, and the most important, proper packing and lubrication.

And a good motto is:

"More turning of gate stems and less of swivel chair stems."

"Know your gate valves!"



Thickness and Weight of Sheets and Plates

Number of Gauge	U.S. Standard Gauge Adopted by U. S. Government July 1, 1893		Birmingham or Stubs' Gauge		American or Brown & Sharpe's Gauge		Thickness of Wire: Washburn & Moen Gauge
	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches
0000000	1/2 .5000	20.4	.....	.....	.....	.....	.....
000000	15/32 .46875	19.125	.....	.....	.580	23.6	.....
00000	7/16 .4375	17.85	.....	.....	.5165	21.0	.....
0000	13/32 .40625	16.575	.454	18.5	.46	18.71	.3938
000	3/8 .375	15.30	.425	17.28	.409	16.71	.....
00	11/32 .343	14.025	.38	15.45	.364	14.88	.331
0	5/16 .312	12.75	.34	13.82	.324	13.26	.307
1	9/32 .281	11.475	.30	12.20	.289	11.80	.283
2	17/64 .265	10.837	.284	11.55	.257	10.51	.263
3	1/4 .25	10.2	.259	10.53	.229	9.36	.244
4	15/64 .234	9.562	.238	9.68	.204	8.34	.225
5	7/32 .218	8.925	.22	8.95	.181	7.42	.207
6	13/64 .203	8.287	.203	8.25	.162	6.61	.192
7	3/16 .187	7.65	.18	7.32	.144	5.89	.177
8	11/64 .171	7.012	.165	6.71	.128	5.24	.162
9	5/32 .156	6.375	.148	6.02	.114	4.67	.148
10	9/64 .140	5.737	.134	5.45	.101	4.16	.135
11	1/8 .125	5.1	.12	4.88	.09	3.70	.120
12	7/64 .109	4.462	.109	4.43	.08	3.30	.105
13	5/32 .093	3.825	.095	3.86	.072	2.94	.092
14	5/64 .078	3.187	.083	3.37	.064	2.62	.080
15	9/128 .070	2.868	.072	2.93	.057	2.33	.072
16	1/16 .062	2.55	.065	2.64	.05	2.07	.063
17	9/160 .056	2.295	.058	2.36	.045	1.85	.054
18	1/20 .05	2.04	.049	1.99	.04	1.64	.047
19	7/160 .043	1.785	.042	1.71	.035	1.46	.041
20	5/80 .037	1.53	.035	1.42	.032	1.31	.035
21	11/320 .034	1.402	.032	1.30	.028	1.16	.032
22	1/32 .031	1.275	.028	1.14	.025	1.03	.....
23	9/320 .028	1.147	.025	1.02	.022	.922	.....
24	1/40 .025	1.02	.022	.895	.020	.82	.....
25	7/320 .021	.892	.02	.813	.017	.73	.....
26	1/56 .018	.765	.018	.732	.015	.649	.....
27	11/640 .017	.701	.016	.651	.014	.579	.....
28	1/64 .015	.637	.014	.569	.012	.514	.....
29	9/640 .014	.573	.013	.....	.011	.461	.....
30	1/80 .012	.51	.012	.....	.01	.408	.....

STANDARD GAUGES*

Sheets, Plates and Wire

Sheet mills roll steel sheets to U. S. gauge unless otherwise ordered. Plate mills usually roll heavy plates, 3/16 and heavier, and light plate No. 8 to No. 12, to Birmingham gauge. In figuring weights of steel plates add to above the allowance for overweight, adopted by Association American Steel Manufacturers. All steel sheets in our *stock are rolled to the U. S. Standard Gauge. Brass is rolled to thickness by Brown & Sharpe's American Gauge. Copper is rolled to thickness by Stubs' or Birmingham Gauge.

* From Link-Belt Catalog.

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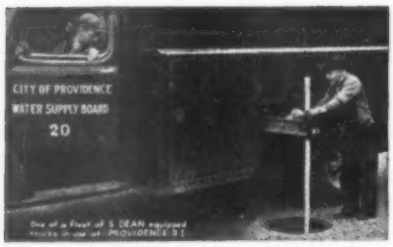
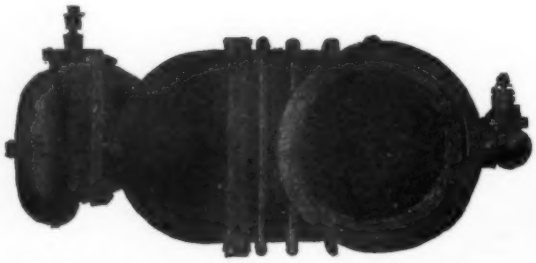


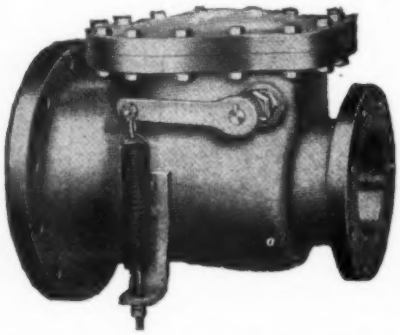
Dean Valve Closing Device from power take-off.

Outside Screw and Yoke Valve.



Valve with Bevel Gearing, Grease Case and By-pass.

Tapping Sleeve and Valve.

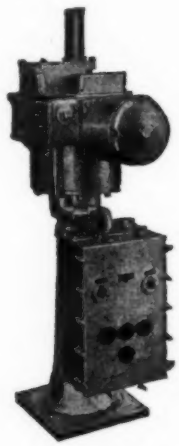


List 340 Clearway Quiet Closing Check Valve.

Rensselaer List 90A Fire Hydrant

Fig. 372 Air and Vacuum and Air Release Valve and Cut-off Valve.

OS&Y Valve with Motor Operating Unit; Mechanical Position Indicator and Stem Cover.



Motor Operated Floor Stand with Integral Control Equipment.

Hydraulically Operated Valve with Square Bottom construction.

NOTE: *We also make many other types and sizes of valves and accessory equipment. Please write for information.*

Floor Stand with Ball Bearing, Grease Fittings and Indicator.

HYDRANT MAINTENANCE

By E. T. CRANCH

Former President and Manager, New Rochelle Water Co., New Rochelle, N. Y.
Now Director Public Works, New Rochelle, N. Y.

GOOD housekeeping is always essential. Women are judged by the manner in which they keep their homes—neatness, if you please. Neatness in water works operation should also be considered essential, and perhaps we should ask for the ladies' advice on our water works "housekeeping" more often than we do.

The Hydrant as a Symbol

Fire hydrants are, without doubt, the most conspicuous and most frequently commented on part of any water works plant. Yet too often these symbols of the water utility suffer from neglect. In the good old days when one could tour the country without worrying about gasoline and tires it was always refreshing to come to a town with bright, freshly painted hydrants, and these always stood out in sharp contrast to the many communities where the hydrants were drab and neglected. We in the water works fraternity should practice "good housekeeping" for our satisfaction as well as for the impression it makes on others.

Paying Procedure

Twice each year every fire hydrant should be given a routine inspection—once in the spring and once in the fall. This inspection should include a pressure test. This test is important for three reasons: it checks on the closing of the drip valve, it reveals any cracks which may have developed from either freezing or external damage, and it proves whether the nozzles are tight. When you first apply the pressure test, always stand back of the hydrant. We have seen serious injury caused by a nozzle flying off and striking a man in the stomach.

Outside of the condition of the hydrant, the pressure test also at times gives valuable information as to underground leaks. The pressure observed should always be compared with that recorded on previous tests. If there is any material reduction, the matter should be at once investigated. This method has sometimes given the first clue to locating serious underground leakage.

A dependable worker given a thoroughly equipped truck for hydrant and valve maintenance work represents money well spent

Importance of Lateral Valves And Their Maintenance

Every hydrant should be equipped with a gate valve on the lateral. This is essential to the efficient operation of any water works system. Otherwise a damaged hydrant may necessitate the shutting down of a considerable length of street main and the putting out of service of several other hydrants while repairs are being made to one. This might easily prove very embarrassing to a water department as well as a water company, especially if a hydrant is damaged during a large fire. If any municipality still has hydrants without a gate valve on the lateral we strongly recommend that such gate valves be installed at the first opportunity they can be obtained.

THE NEW ROCHELLE WATER CO.,
NEW ROCHELLE DIVISION
New Rochelle, N. Y. ..... 19.....

DAILY HYDRANT REPORT

No. of Hyd.	STREET	Press.	Time Taken	Greased	Packed	New Bolts	Painted	Numbered	Unusual Repairs

FORM 6 IM.-6-37

Fig. 1.—Daily Hydrant Report Form Used for Recording Routine Maintenance Inspection and Repairs.

Report Records

Figure 1 is a form of daily report for work on hydrants which we have found very satisfactory. It will be noted that this form calls for "No. of Hyd." We have found it convenient to number all of our hydrants serially. This number is stenciled at the base of the hydrant on the side facing the street. Figures about 2 inches high are used. It will be noted that following the pressure column ("Press.") there is a column "Time Taken." In comparing pressures it has been found helpful to know the time of day at which each pressure was taken. The next five columns are simply checked off as the operations are performed. In the last column any unusual repairs required are noted.

Painting Policy and Practice

We have found it good policy to paint all hydrants once a year. In this way the hydrants always have a well groomed look and are a credit to the company. If a high grade enamel paint is used, the hydrant may look quite passable for a period of two years, but at the end of two years it is difficult to apply a new coat of enamel satisfactorily without a lot of wire brushing on the old coat. We have found a semigloss paint to be most satisfactory. It holds up very well for a year and is easy to

B.P. 13640#

NO.

LENGTH OF LATERAL ft. HIGHWAY ☐ PRIVATE ☐

DIAM. OF LATERAL in. CUTLETS

SMITH TAP ☐ REG. VALVE ☐

DISTANCE HYD. TO VALVE

DIAM. OF STREET MAIN in. HYD. BBL. SIZE in.

ELEVATION ft. DATE

REMARKS

DATE	PRESSURE AT INSPECTION	DATE	PRESSURE AT INSPECTION

DATE	HYDRANT		PIPE		VALVE SIZE	G.B. OR M.H.	WORK ORDER
	MAKE	VALVE SIZE	SIZE	LENGTH			

NO.

TYPIST PLEASE NOTE—THIS SCALE CORRESPONDS TO TYPEWRITER (PICA) SCALE—SET PAPER GUIDES SO THAT CARD SCALE WILL REGISTER WITH MACHINE SCALE WHEN CARD IS TURNED INTO WRITING POSITION. START INDEX THREE (3) POINTS FROM LEFT EDGE OF CARD. USE OTHER POINTS OF SCALE FOR OTHER DIVISIONS OF VISIBLE TITLE. SET TABULATORS TO INSURE PERFECT ALIGNMENT OF EACH DIVISION OF INFORMATION. FOLD BACK OR REMOVE STUB AFTER TYPING. USE NEW TYPEWRITER RIBBON.

KARDEX VISIBLE DIVISION 886-200-85814-'38 REMINGTON RAND INC.—13 Printed in U.S.A.

Fig. 2.—Permanent Maintenance Record Form of the Kardex System.
(Gives all essential operating information at a glance. Also provides the important continuing property record now increasingly demanded by State Public Service Commission.)

repaint. We have painted as many as 140 hydrants with one gallon of paint.

Immediately after a hydrant is painted, be sure a "wet paint" sign is securely fastened to the hydrant. It is surprising how much clothing can be damaged by brushing up against a freshly painted hydrant, and unless the wet paint sign is there, the water utility (company or department) will be faced with paying damages.

We have tried using a portable spray pump but have found it wasteful of paint and that we could paint just as many hydrants per day by hand.

Packing and Lubrication

For packing we use jute impregnated with tallow. This has proven very satisfactory. For lubrication we use a grease with a graphite base. We have tried various types of grease and the graphite base grease is the only one we have found which will not cause the caps to stick, especially in cold weather.

Cap Chains Useless Impedimenta

The common practice is to have the caps fastened by chains to the hydrant barrels. We found the fire departments in trying to get connected to a hydrant in a hurry were often greatly annoyed by the chain. We therefore tried the experiment some ten years ago of removing all the chains. We feared that caps might get lost or misplaced during a fire so we equipped each fire truck with an extra cap, but to date none of these extra caps have been used and the fire departments are greatly pleased with the elimination of the chains.

It is essential at all times to have the full cooperation of the fire department and arrangements should be made to have the fire department report to the water department after it has used any hydrant. The water department should then make a special inspection of this hydrant to see that everything about it is all right. The fire department should also be instructed never to force a hydrant in trying to close it. If it does not close readily, have the water department or company notified.

Continuing Records

Figure 2 illustrates a form of permanent hydrant record which is used in a Kardex file. This card gives all the essential operating information as well as that necessary for the maintenance of a continuing property record such as is required now by several Public Service Commissions.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						⅞ inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch						1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	7	10	12	13	15	17	11	14	17	20	23
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost per 100′ 2½″ hose	16	20	25	30	34	39	22	29	36	42	49
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	253	292	326	357	386	413	307	354	396	434	469

ACCOUNTED-FOR WATER AND UNBILLED REVENUE

A Method for Estimating Both Between Scheduled Meter Readings

By CHAS. E. MOORE
General Manager, Roanoke Water Department, Roanoke, Va.

THE war brought forcibly to the attention of the home front the need of conservation of the critical materials.

The water department's part in that program may be generally divided into two main features. The first requires that it place its plant in the best over-all condition, the main point of which is to account for all of the water taken from its source of supply and put into its distribution system.

Where communities are served by an unlimited gravity supply requiring no treatment, conservation plays a very minor part. On the other hand if supply is treated chemically and is also pumped, reducing the volume introduced into the distribution system to an economic level, produces a saving in chemicals, in fuel, and by their reduction, a reduction in the need for transportation facilities.

The other feature of the water department's part in the conservation program is to educate its consumers to be as conservative in their use of water as is possible.

That water department, which renders its service on a flat rate basis, has no exact measure of the use of its service made by individual customers. It has a peculiar problem that will not be answered by this article which is directed to those plants where practically all customers are metered.

Basic Assumptions

The practice of billing all customers monthly is rapidly being eliminated, and meter readings are now being taken at longer intervals than heretofore. For the purpose of discussion, we may assume that quarterly meter reading has been adopted and, further, that in the interest of economic commercial work one-third of the total customers are billed each month. Two further assumptions are made: That the individual meters serving the customers are read all during the month, and that bills resulting from the meter readings are made and delivered within two or three days after the meters are read.

Such practice makes the determination of the quantity of water delivered to the customer, as compared with the total quantity pumped, something of a problem. This article undertakes to solve that problem by determining what percentage of the pumpage is actually sold.

The foregoing meter reading practice produces a consumption figure for one-third of the city, closely approximating the total quantity sold for a three-months' period for that entire section as of the middle of the month.

During any quarter period the other two sections have already been billed for a part consumed in the quarter and have also received service of an undetermined quantity for the balance of this quarter. The problem of determining the quantity delivered to all sections, and compared with the quantity of water pumped as of the last day of the month, now presents itself. This article submits for consideration the reconciliation between the water pumped and the water billed by a method of graphs.

Preparation of Chart for Accounted-for Water

Using cross-section paper with a convenient scale, lay out on a vertical axis the total gallons to be pumped for the 14½ months' period beginning with October 15th; on the horizontal scale mark off an equal space representing the 14½ months. The variation in the number of days in the different months will be found to be insignificant and of no real purport. The accompanying figure shows the chart.

At the top of this graph prepare a table of eleven columns as shown. Col. 1 contains the names of the months from December through December inclusive; i. e., 13 months. Column 2 provides for the actual known deliveries of Section 1 for each quarter of the year. Column 3 provides for an accumulative figure of Section 1 to date. Columns 4, 5, 6, and 7 provide for similar figures of Sections 2 and 3 respectively. Column 8 provides for the actual quantity pumped for each month; column 9, the accumulated pumpage. Column 10 provides for the estimate of the water delivered to the customer as taken from the graph; and column 11 is for the determination of the percentage ratio between water accounted for and the water pumped.

Step 1. The first step in preparing the graph is to make an estimate of the quantity of water used by 1/3 of the consumers (i. e., Sect. 1) in the previous quarter as determined from meter readings taken during the month of January. This value is given in Col. 2. Consider that amount as billed the customer as of the middle of January. This is point 1 on the graph.

This estimate is, of course, based on past history. On the graph indicate this quantity by a point half way between the December and the January line.

Step 2. Make a similar determination of the quantities that will be billed for Section 2 during the month of February, and then the third section during the month of March. These are points 2 and 3 respectively, and are the data values given in cols. 4 and 6.

Step 3. Draw on the graph a portion of a line beginning in time three months prior to each point (1, 2, and 3) at zero, and draw the three lines to the end of December only. See heavy lines on graph. It is suggested for convenience that these three lines be drawn in three colors.

Step 4. Add the ordinates of the three lines where they cross the December line and indicate their sum at the end of December by a point, "Est." This ordinate represents your estimate of the water actually delivered as of December 31st. Enter this estimate in the table opposite the top December under Col. 10 "Acct. For."

Step 5. With little or no previous data, you must now assume a factor of accounted-for water and enter on December line under Col. 11. Apply this factor to the "Acct. For" estimate (Col. 10), determine the "Gross" water that has been pumped corresponding to this estimate of water delivered, and enter this pumpage figure on the December line under Col. 9 "Gross."

Step 6. At the end of January, record on the January line in Col. 3 the pumpage for the month of January. Add this value to the Dec. "Gross" in Col. 9 above, and enter the sum on the January line under Col. 9, Gross.

Step 7. When the January billings have actually been determined and corrected to the known unmetered usage. plot this corrected figure half way between December and January (i. e., Jan. 15) and redraw the correct line from zero as of the 15th of October through this point, and project the line to January 15 for point a. Next project the curve on the graph for Sections 2 and 3 to January 31 in the same manner, thus obtaining points b and c on the graph.

Step 8. Now add the three ordinates of the three sections as of January 31 and record on the graph their total, point "A." Reading from the graph, insert this figure in Col. 10, Accounted-For. This value with the Jan. value in Col. 9 will permit a new determination of the percentage accounted-for to be entered in Col. 11.

Step 9. The process is repeated in subsequent months, and each quarter the estimate previously made is corrected to the known facts. With this initial very close determination of the percentage accounted-for, the succeeding years' graphs will be correspondingly more accurate.

As each month passes, points 4, 5, 6, then 7, 8, 9, etc., will be definitely determined, with points d, e, and f, then g, h, and i, representing the estimates at the end of each month; the latter groups adding up to B and C, and so on for the year.

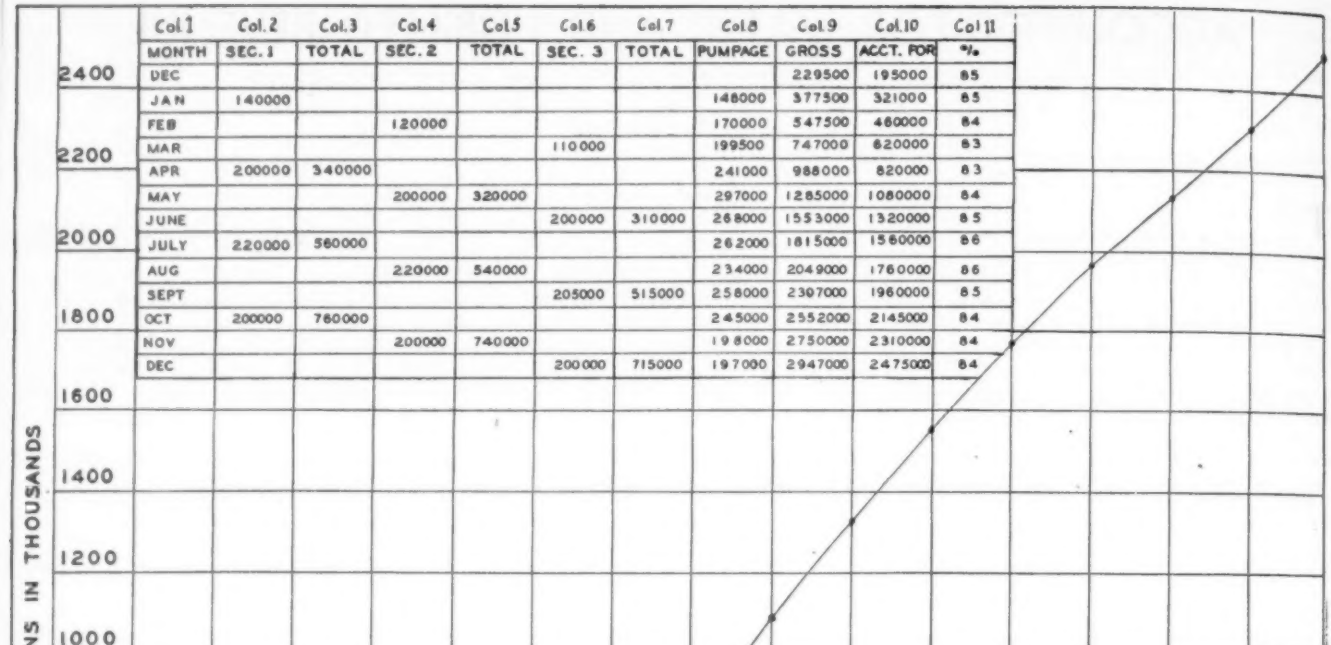
It is to be remembered that, while this graph is for the purpose of determining the leakage in the distribution system, it will also include the loss due to under-registration of meters.

Unbilled Revenue

Service to consumers is rendered and costs paid before consumer is billed. Modern accounting practice requires an estimate of the revenue to be derived by a future billing of service already rendered.

The determination of unbilled revenue follows exactly the same fundamental scheme as outlined above. Again use a table of eleven columns. In Cols. 2 to 7 incl. record the regular quarterly billings and the accumulation by quarters. In the subsequent columns, Col. 8, 9, 10, are the accumulated gross billings, the projected revenue, and the difference between the two; that is, unbilled revenue. Col. 11 will show the increase or decrease in this unbilled revenue. (Note, no graph or chart appears herewith for this Unbilled Revenue calculation.)

The curve is started in the same manner as outlined in Step 1 above. An estimate of the revenue for the first three quarters is made, thus determining as of December 31 that portion al-



Col 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11
MONTH	SEC. 1	TOTAL	SEC. 2	TOTAL	SEC. 3	TOTAL	PUMPAGE	GROSS	ACCT. FOR	%
DEC								229500	195000	85
JAN	140000						148000	377500	321000	85
FEB			120000				170000	547500	460000	84
MAR					110000		199500	747000	620000	83
APR	200000	340000					241000	988000	820000	83
MAY			200000	320000			297000	1285000	1080000	84
JUNE					200000	310000	268000	1553000	1320000	85
JULY	220000	560000					262000	1815000	1560000	86
AUG			220000	540000			234000	2049000	1760000	86
SEPT					205000	515000	258000	2307000	1960000	85
OCT	200000	760000					245000	2552000	2145000	84
NOV			200000	740000			198000	2750000	2310000	84
DEC					200000	715000	197000	2947000	2475000	84

Chart and Table for Determining Accounted-For Water

(See steps 1-9 in accompanying text for details of construction—the chart for unbilled revenue is developed in the same manner.)

ready delivered for the three sections of the city not yet billed. This is, of course, the unbilled revenue as of December 31 and also equals the projected revenue as of this date.

When monthly billings are known, add the accumulated gross billings in Col. 8, complete the graphs to end of the month in the same manner and upon the same theory as used in the pumpage figures.

The projected revenue determined by the summation of the three alternates is read off the graph and entered in Col. 9. The difference of the two is the new unbilled revenue figure to be entered in Col. 10 with the increase or decrease as the case may be entered in Col. 11. This last column should begin with the low pumpage period, increase to a peak in the high consumption period, and then decrease to approximately its starting point, other general business conditions remaining constant.

It will be found that the time required to prepare these graphs, once they are started and understood, is insignificant. On the other hand the management is possessed of a very accurate determination of the accounted-for water and the relationship between revenue and expense; for, under this quarterly billing scheme and a uniform rate of reading meters, expense of operation will tend to run ahead of actually billed revenue.

HORSE-POWER AND ELECTRICAL DATA

(a) 1 H.P. = 0.746 KW. = 746 watts.

(b) Brake H.P. $= \dfrac{\text{KW. input}}{0.746} \times$ motor efficiency.

(c) Water H.P. $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960}$.

(d) H.P. to lift water $= \dfrac{\text{g.p.m.} \times \text{head in ft.}}{3960 \times \text{pump efficiency.}}$

STANDARDS FOR WATER SERVICE

By MARSDEN C. SMITH
Chief Engr., Dept. of Public Utilities, Richmond, Va.

IF YOU call your electrical contractor and ask him to furnish and install a 10-hp. electrical motor, he knows the service standards of the local electric utility and can order the motor with assurance that your installation will be successful.

But what of the engineer, architect or plumber, when asked to furnish and install plumbing or other water consuming equipment? What is the standard pressure, and what size service line and meter does the local water utility require?

Inquiries have shown that only a few water supplies have standards for either. Many of those questioned suggest that this lack of standards is due to the diversity in procedure in various cities and this, in turn, causes the individual to hesitate to assume the responsibility of voluntary action.

This diversity of practice must be admitted, but that is no reason for us to fail to set up standards, for surely, just as the electrical companies have found it often necessary to do, we can change these standards if found to be wrong.

Pressure Standard

It is obvious to anyone that the most desirable pressure to select as the "standard" is that pressure at which the total cost of water service in the area served shall be a minimum. Unfortunately, that pressure is not as simple to determine as it is to define. Most privately owned residential property consists of structures that use water at not more than 30 feet above the sidewalk. If to this 30 feet of elevation we add an allowance of 16 feet for friction loss from the main to the outlet, it is evident that a standard pressure of 25 pounds per square inch at the sidewalk level should be adequate for residential areas.

But the heights of apartment and business buildings vary through such wide limits that the problem here becomes one of determining how high in the air the water utility should agree to deliver water. Perhaps it is fortunate that we have an upper limit of 50 psi as a fairly well established maximum for general use. This results from the well-known fact that excessively high pressures are objectionable, even if available without pumping, because such pressures result in excessive leakage, create troublesome water hammer and unreasonable plumbing maintenance cost.

Hence it appears that the operator may rationally select as a standard pressure at the sidewalk any value between the limits of 25 and 50 pounds. In accepting these limits, the operator finds that he may reasonably agree to deliver water to any height above the sidewalk that he may elect between 30 and 85 feet.

But since it costs real money to pump water, and since leakage is increased with increasing pressure, the operator must find justification for the increased operating expenses created with each pound over the minimum necessary that he selects for his standard pressure.

It may be of interest to follow some of the threads of thought that were used in one city in determining its standard pressure.

Basis of Determining Standard Pressures

Fire services are highly important, but it is surprising to many to see how relatively small a reward is to be had by increasing main pressures. Surely none but the smallest community can rely on general service pressures for fighting any but unimportant fires. Instead, either mobile fire pumps (engines) or a separate fire system must be available. Hence, if an adequate quantity of water is available at 25 psi, and since the engine is not appreciably helped by 50 psi rather than 25 psi inlet pressure, there can be no incentive on this score for the higher pressure standard.

It is true that sprinkler systems will generally need more than 25 pounds at the sidewalk. But surely this additional pressure can be furnished by the owner of the sprinkler installation at a vastly more equitable cost than by raising the pressures throughout the entire area.

And then, as to the number of properties satisfactorily served within the limits that we have set up. Since the minimum will give reasonable service to an average three-floor building, it is evident that by far the larger number of outlets in most communities can be successfully served by the minimum pressure now being considered. Of course, the per cent of total use that will be included between the two limits of 25 and 50 pounds will be different in every city. Thus it is certain that if there is a large part of the total use at elevations near the upper limit of 50 pounds, it is highly probable that there will be yet a large part of the total use that it has been determined to be unreasonable to supply without auxiliary building pumps.

Consequently, the only consideration from the standpoint of the consumer, both in normal use and fire protection, is how many buildings will be served by any increase above the 25-pound minimum, and how far does the water utility wish to go in assuming this increased pumping expense.

On the other hand, we should not lose sight of the fact that if we are to maintain a minimum standard at all points of a system, certainly we must exceed that minimum in most of the area served. Topography rarely, if ever, is so ideal as to cause the natural elevations to compensate for pipe friction between the supply and the consumer. And certainly it is unwise to have too many separate pressure areas; these not only are expensive to create, but a multiplicity of "dead-ends" is one of many undesirable results. Thus, even if we select 25 pounds as our standard pressure, it is certain that most of the area will of necessity have pressures considerably in excess of this minimum.

However, it must be recognized that an actual sidewalk pressure of 25 pounds can hardly be supported as reasonable for the modern town or city. And so, admittedly, rather as a compromise than from any exact scientific deduction, 35 pounds at the sidewalk was made the standard water service pressure.

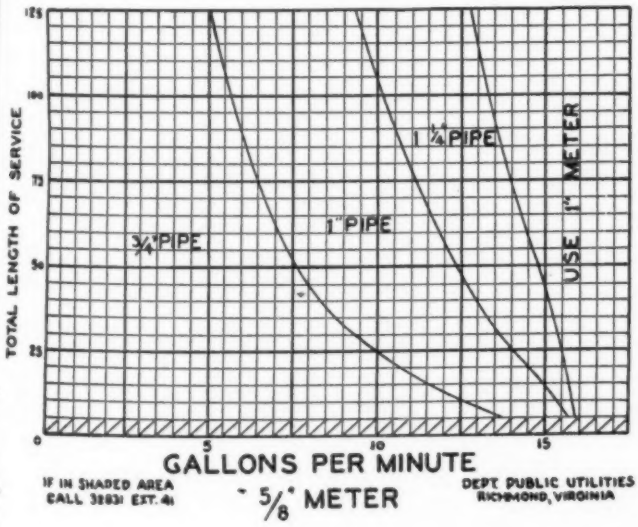


Chart I

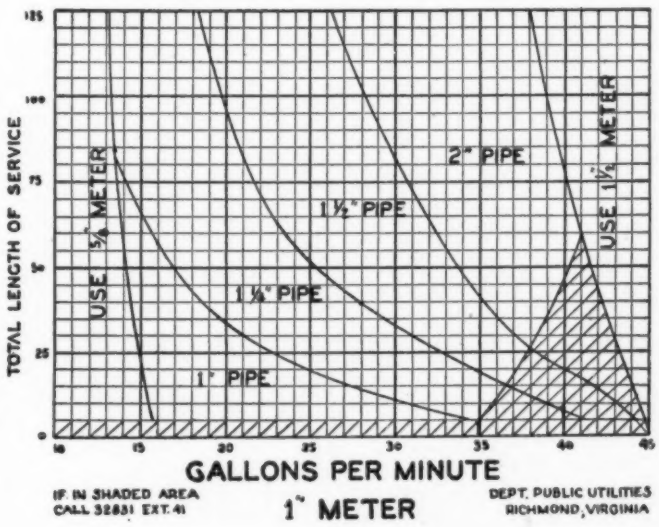


Chart II

The city does not guarantee that this pressure will always be available, but it assumes responsibility to make such improvements as may be necessary to maintain this minimum when service is normal. But every consumer is notified that the existence of pressures greater than this standard, no matter how long they have been or may yet be available, are above normal and may at any time be reduced to the standard.

In practice, this standard is extremely helpful to all parties. For example, if a fire service is installed which is approved by the Fire Underwriters because of an existing pressure of 50 or more pounds, the property owner is notified that the city does not guarantee to continue service at that pressure and that it recommends that provision be made to add fire pumps if in the future the city finds it advisable to reduce pressures to the standard of 35 pounds. The owner thus avoids the necessity of installing the pumps at the time of constructing the fire system,

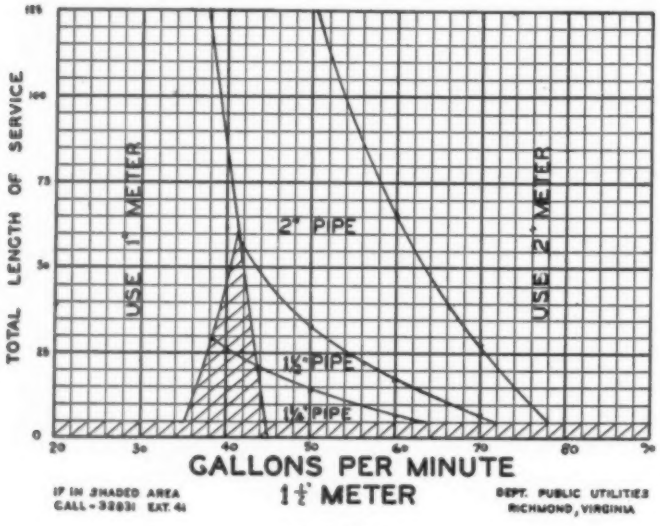


Chart III

but if they become necessary, they may be installed in the future at much less expense if provision is made for them at the time of construction.

Size and Services and Meters

If now pressures are to be set at a value that leaves no great margin for satisfactory service, the size of the service and meter to be used must be accurately determined for each installation. But it was first necessary to decide what part of the available standard 35-pound pressure should be allotted to the friction losses in the meter and service pipe. While this presents a highly involved study, if it is to be scientifically determined, many considerations indicated that a design which would consume 7 pounds of head would be rational. Consequently there is a proper combination of meter and service pipe size (the quantity of water and the total length of service pipe being known) through which the friction loss will not exceed 7 pounds.

If the water is to be used at a constant rate, no serious problem is presented in selecting the most economical combination of meter and service pipe to deliver that quantity at a 7-pound loss. But this ideal is rarely if ever obtained in practice, and so in the accompanying tables an effort has been made to allow for the diversity of use in such a way as to simplify the problem, yet not seriously err from the most successful and yet economical design.

The use of these data can best be understood by reference to actual examples. But, here it should be noted that the rates of flow are not the actual quantity of water that may be supplied to any appliance; this is because of the influence of the diversity of factors in any installation that is large enough to approach the capacity of the smallest meter and service that it is practical to use. Also, the apparently erratic value assigned to the multiplier in Table II for outlets numbering between 19 and 50 may be observed. This is the result of an effort to cover the transition from the larger residences with their relatively few occupants to apartments with their greater number of persons per outlet.

The Cost of Services and Meters

The problem of determining the actual cost of individual small services is much too involved for practical application. In some instances a single service is installed, whereas in others a hundred or more may be grouped for the various units of a real estate development. Not only does this variation make the estimate of the cost a highly involved process, but the cost of repaving varies through even wider limits. And so in Table III the *average* cost of any service up to and including 2-inch meters with 3 inch pipe is given.

By coding all such cost collectively, it is easy to determine whether or not the money being collected for the services on the flat charge basis is greater or less than the actual cost. If, because of a major change in the cost of material and labor, the units of Table III need to be revised, a revision is made if it is believed this change of cost will be effective for a sufficient length of time to warrant the change, but not until after 90 days' notice to all licensed plumbers and contractors to the effect that such a revision is planned.

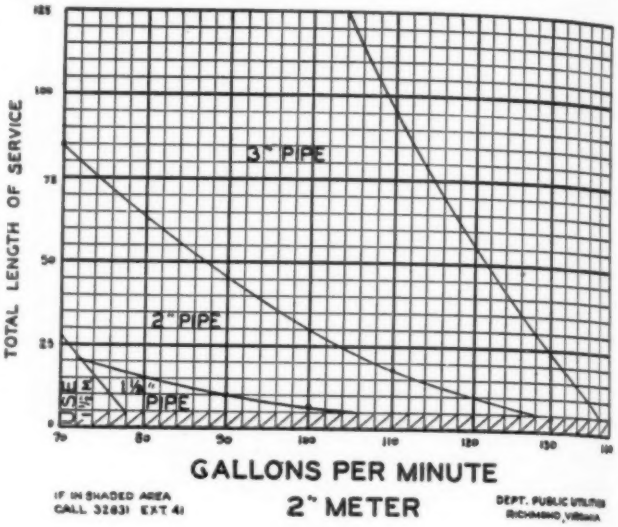


Chart IV

Examples of Application

Through the use of Table I and a list of equipment to be installed the plumber who estimated on a cost of water service for a residence in the 5400 block, Grove Ave., Richmond, Va., determined the highest possible demand in the following manner:

(A) Two baths, each having one tub and shower, one lavatory and one toilet.
(B) One bath having a lavatory and toilet but no tub or shower.
(C) One kitchen sink.
(D) One laundry tub.
(E) One furnace connection.
(F) Three silcocks.

Appliance	Outlets	Gals. per minute
(A) Tubs	$2 \times 2 = 4$	$2 \times 6 = 12$
(A) Lavatories	$2 \times 2 = 4$	$2 \times 4 = 8$
(A) Toilets	$1 \times 1 = 1$	$1 \times 4 = 4$
(B) Lavatory	$1 \times 2 = 2$	$1 \times 4 = 4$
(B) Toilet	$1 \times 1 = 1$	$1 \times 4 = 4$
(C) Kitchen sink	$1 \times 2 = 2$	$1 \times 5 = 5$
(D) Laundry	$1 \times 4 = 4$	$1 \times 8 = 8$
(E) Furnace connection.	$1 \times 0 = 0$	$1 \times 0 = 0$
(F) Silcocks	$3 \times 1 = 1$ (Max.)	$3 \times 3 = 3$ (Max.)
Total	19	48

Then by reference to Table II, for the 19 outlets he found the multiplier to be .21. He then multiplied the maximum demand by this multiplier ($48 \times .21$) to obtain the maximum demand of 10 gpm. as the flow to be expected sufficiently often to warrant designing the service for such flow. The factors listed in Table II are what may be called "most probable numbers," in that they are based on the most probable use of combinations of the 19 outlets simultaneously.

He next determined the total length of the service, which is the actual distance from the main in the street to the point in the house where branches take off from the service pipe. In this case the house is set back 20 feet from the property line and the first riser from the service is 52 feet from the front of the house, or 72 feet from the property line. The main is to be 6 feet south of the center line of the street and the house is on the north side of the 66-foot wide Grove Ave. The length of service from the main to the property line will be one-half of the 66 feet plus 6, or 39 feet. The total length of service, therefore, is 72 plus 39, or 111 feet. Referring to Chart I, we see that a 1-inch service pipe with a ⅝-inch meter is all that is needed for this service required to supply 10 gpm.

This example is used because it is a borderline case. Although a 1-inch pipe with a ⅝-inch meter will be sufficient, reference to Table III with Class 2 paving under a 66-foot wide street indicates the price of this service to be $146.50, whereas a 1¼-inch pipe with ⅝-inch meter will be only $9.50 more. This slight difference in cost fully justifies playing safe and installing a 1¼-inch service pipe instead of the 1-inch line.

Example 2

A service building is to have the following equipment:

TABLE I

Demand of Various Appliances

Appliance	Number of outlets	Gals. per minute
Domestic kitchen sinks	2	5
Commercial kitchen sinks	2	7
Shower or shower and tub combined	2	6
Tub or tub and shower combined	2	6
Lavatory	2	4
Tank toilet	1	4
Domestic laundry tubs	4	8
Silcocks	1 (Max.)	3
Furnace connections	0	0
Steam table sinks	1	6
Soup kettles	2	20
Coffee urns	1	5
Potato peeler	1	8
Dish washer	2	8
Glass washer	2	6
Slop sinks	1	3
Drinking fountains	0	0

The supply of water to Flushometer toilets and urinals should be treated separately from the standard appliance in accordance with the following schedule:

No. of Units	Toilet GPM	Urinal GPM	No. of Units	Toilet GPM	Urinal GPM
1 or 2	30	2	15 to 30	75	8
3 to 5	45	4	31 or more	90	12
6 to 15	60	6			

TABLE II

Demand and Load Factors

Total No. of outlets	1	2	3	4	5	6	7	8	9
Multiplier	1	.75	.635	.575	.52	.465	.415	.375	.345

10	11	12	13	14	15	16	17	18	19	20
.32	.30	.28	.26	.25	.24	.23	.22	.22	.21	.22

21	22	23	24	25	26	27	28	29	30	32
.22	.24	.26	.28	.30	.32	.33	.33	.34	.34	.34

34	36	38	40	42	44	46	48	50	55	60
.34	.34	.34	.34	.34	.34	.34	.34	.33	.32	.31

65	70	75	80	85	90	95	100	More than 100
.30	.29	.28	.27	.26	.25	.24	.23	.22

12 Toilets (Flushometer)
4 Urinals (Flushometer)
17 Lavatories
17 Showers
1 Kitchen sink
1 Coffee urn
2 Drinking fountains

Again the number of outlets and the maximum demand were determined from Table I.

Appliances	Outlets	Gals. per minute
Lavatories	17 × 2 = 34	17 × 4 = 68
Showers	17 × 2 = 34	17 × 6 = 102
Sink	1 × 2 = 2	1 × 7 = 7
Coffee urn	1 × 1 = 1	1 × 5 = 5
Drinking fountains	2 × 0 = 0	2 × 0 = 0
Total	71	182

Here there were 71 equivalent outlets and a potential maximum instantaneous demand of 182 gallons per minute. From Table II, under 71 outlets, the factor applied indicates 182 × .29 = 53 gpm. to be the maximum demand to be assumed for all appliances other than the flushometer toilets.

To this was added the expected demand of the toilets and urinals, which was determined from Table I as follows:

	GPM
12 Flushometer toilets	60
4 Flushometer urinals	4
Other appliances	53
Total	117

The distance from the main to the first branch piping in the building is 50 feet. From Chart III it is seen that to carry 117 gallons 50 feet requires a 3-inch service pipe with a 2-inch meter.

Assume this service to be supplied from a main in a brick paved alley 20 feet wide. To determine the cost from Table III of Class 2 paving under the column headed "Street Width 0-26 feet" and on the line for 3-inch service pipe and 2-inch meter, find the average cost to be $316.00.

Note: All of these designs and schedules of cost were based on the use of Type K copper pipe and bronze meters and have had to be temporarily modified during the existing state of war.

Favorably Accepted by Master Plumbers

Sets of the four graphs reproduced with this paper are supplied Richmond plumbers and contractors. It is noted that a telephone number appears on each chart so that the estimator may obtain further information, interpretation or guidance in the use of these charts.

This method of determining costs and design has been most favorably accepted and has proven entirely successful in all cases in which it has been used.

TABLE III

Estimated Cost of Services Including Paving

FOR CLASS I PAVING

(Paving that does not require concrete base, including all alleys, penetration and plain spall paving)

Service Length (ft.)		10	15	21	26	31	37	46	55
Street Width (ft.)		0-26	26-35	36-45	46-55	56-66	67-80	81-100	101-120
Pipe Diameter (Inches)	Meter Size	COSTS							
¾	⅝	$ 41.25	$ 51.00	$ 62.75	$ 72.50	$ 82.00	$ 94.00	$111.50	$129.00
1	⅝	43.25	53.00	65.00	75.00	85.00	97.00	114.50	132.50
1¼	⅝	48.00	58.00	71.00	81.50	92.00	104.50	123.50	142.00
1	1	58.00	68.50	80.50	90.50	100.00	112.00	130.00	148.00
1¼	1	63.50	73.50	86.50	97.00	107.50	120.00	139.00	157.50
1½	1	69.00	80.50	94.00	105.00	116.00	129.00	149.00	169.50
1½	1½	94.00	107.00	120.50	131.50	143.00	156.00	176.50	196.50
2	1½	105.00	119.50	135.00	148.00	161.00	176.00	199.00	222.50
2	2	234.00	247.00	262.00	275.00	288.00	305.50	326.50	350.00
3	2	289.50	305.50	325.00	340.00	357.00	376.00	405.00	433.50

FOR CLASS II PAVING

(Paving that does require concrete base—i. e., all paving other than class I)

Service Length (ft.)		10	15	21	26	31	37	46	55
Street Width (ft.)		0-26	26-35	36-45	46-55	56-66	67-80	81-100	101-120
Pipe Diameter (Inches)	Meter Size	COSTS							
¾	⅝	$ 60.00	$ 80.50	$104.00	$123.50	$143.00	$166.50	$201.50	$236.50
1	⅝	63.50	83.00	107.00	126.50	146.50	170.05	206.00	242.00
1¼	⅝	68.50	89.50	114.50	135.00	156.00	181.00	218.50	256.00
1	1	79.00	98.50	122.50	142.00	162.00	186.00	221.50	257.50
1¼	1	84.00	105.00	130.00	150.50	171.50	196.50	234.00	271.50
1½	1	91.00	113.50	140.00	162.50	184.50	211.50	251.50	291.50
1½	1½	116.00	140.50	167.00	189.50	211.50	238.50	278.50	318.50
2	1½	128.50	155.00	185.00	209.50	234.00	264.00	308.50	353.00
2	2	257.50	282.50	312.00	336.50	361.50	391.00	435.50	280.00
3	2	316.00	345.00	380.00	409.00	438.00	473.00	526.00	578.00

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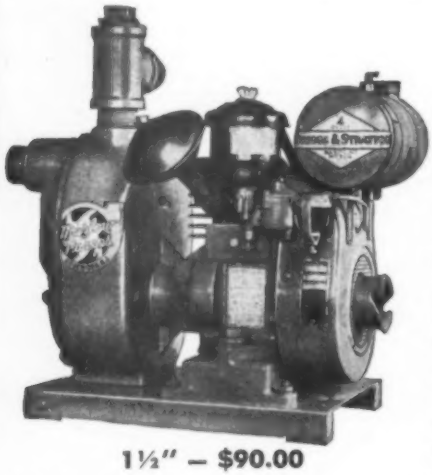

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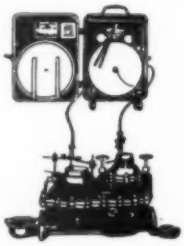

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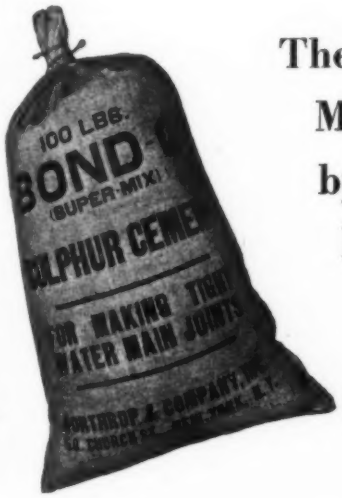

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BOND-O is a jointing compound so carefully blended that every bag assures joints that are tight, strong and flexible.

BOND-O is manufactured, serviced and sold by a group of men who know the jointing compound business from top to bottom. These men, collectively, represent more than 110 years' experience in the water works field. Over 50 of these years have been specifically devoted to the sulfur-base jointing compound industry.

BOND-O is made from carefully selected and proven ingredients properly compounded and thoroughly mixed. No expense has been spared in selecting the correct machinery and expert supervision in manufacturing. A positive control for uniformity assures every pound of BOND-O to be exactly the same.

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Fig. 307
BOND-O Gasoline Furnace
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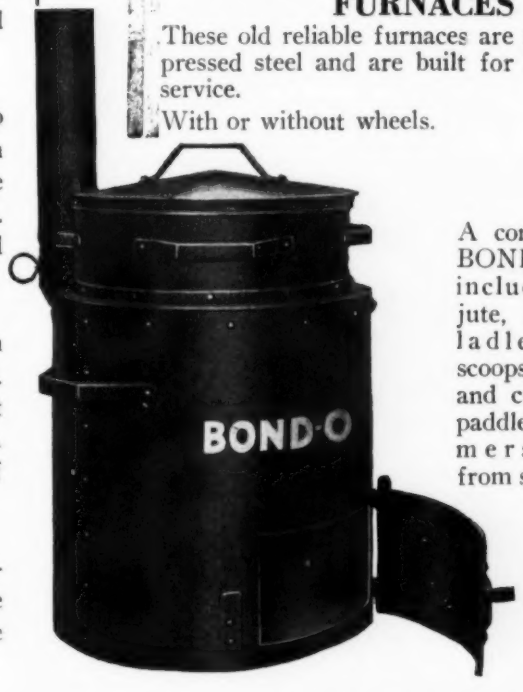
With or without wheels.



A complete line of BOND-O equipment including braided jute, pouring pots, ladles, funnels, scoops, yarning irons and cutters, stirring paddles and hammers is available from stock.

THE "MUD-HOG"

An Air-Lift Subaqueous Trencher Which May Also Be Used for Handling Sludges, Sand, and the Like

By HARRY U. FULLER

Chief Engr., Portland Water District, Portland, Me.

BECAUSE of war conditions in Portland, Maine, in 1943 it became necessary to devise a method of digging a trench 500 feet long in 30 feet of water without the use of the customary bucket on a derrick.

The material in the harbor bottom is a plastic blue clay and the method adopted was to cut the clay with water jets and remove it by air-lift of the heavy clay suspension.

The principle of the air-lift pump is that a column of water in a vertical pipe when full of air bubbles is lighter than the water on the outside of the pipe, and the unbalanced force causes the column of air-water mixture in the pipe to rise as long as air is forced into the pipe.

On page 146 of the Reference and Data Section in *Water Works and Sewerage* for May, 1937, the principle of pumping by air-lift is effectively explained in detail.

The air-lift trencher has two elements—the water jets and the air-lift pump. These were built into one unit, which could be easily handled and suspended from the boom of a lighter.

Construction of Trencher

The air-lift trencher (see cut) consisted of lengths of 8-in. pipe screwed together, reaching from the harbor bottom to a few feet above the deck of the lighter, about 40 feet.

On the upper end was an 8-in. quarter bend with a 3-ft. piece of 8-in. pipe screwed into it to throw the mud away from the lighter. The lower section of the 8-in. pipe was 5 ft. long and around it, 6 in. from the bottom, was welded a 16-in. steel drum 8 in. high. The drum was sealed top and bottom with ring plates. A 2-in. air pipe was attached to the drum through the top ring plate. Through the pipe within the drum were five equally spaced 11/16-in. holes for admission of air from the drum to the lift pipe.

On the other side of the 8-in. lift pipe was the 3-in. water jet pipe with 1-in. tees at 8-in. intervals. Into each tee was screwed a 1-in. one-eighth bend and into the bend a 4-in. long nipple, flattened at the outer end to leave ¼-in. wide opening to produce flat cutting jets.

The water pipe was carried by fittings around the 8-in. pipe under the drum with three jets pointing downward. The three pipes, from the lower section to the top of the trencher, were held together by welded braces.

The dimensions of the trencher were taken from an article in the *Engineering News Record* on June 5, 1941, telling how an air lift was used for cleaning mud and sand out of cofferdams.

The same proportions found to work successfully in the 12-in. lift in New York were used in building the tools herein described.

The areas of the air ports and air drums and the capacity of the air compressors were thus proportioned to the area of the air-lift pipes used on the Portland trenchers.

Three of these air-lift trenchers were built: An 8-in. pipe with 11/16-in. air ports inside the drum, requiring 400 cu. ft. of free air per minute. A 5-in. pipe with 7/16-in. air ports requiring 150 cu. ft. of free air per minute. A 4-in. pipe with ⅜-in. air ports, requiring 100 cu. ft. of free air per minute.

All three units worked very well with one-third less air than called for in the article referred to. However, with the full amount of air called for they worked much better.

When the proper amount of air is being applied, the flow is steady. If irregular flow or surging develops the amount of air must be readjusted. One outstanding advantage of this type of equipment for pumping mud, sludge, grit, etc., is the smooth interior waterway which permits anything which enters the lower end to continue to the outlet unobstructed.

Method of Use and Possible Applications

The trencher was hung from the side derrick boom on the lighter. Gasoline-driven air compressors of the required capacity were placed on the deck of the lighter and connected to the upper end of the 2-in. air pipe with air hose.

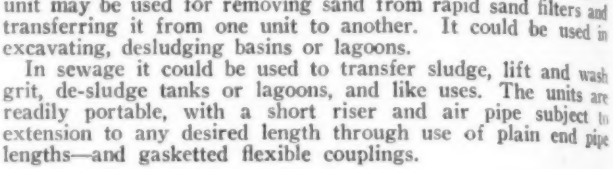
To provide water for the jets, a gasoline-driven fire pump, with a capacity of 500 gallons per minute at 100 pounds pressure, was also placed on the deck of the lighter and connected through fire hose to the upper end of the 3-in. water pipe. Because of the liberal diameter of the water pipe running to the foot of the trencher a large part of the 100 pounds pressure at the pump was available at the cutting and stirring jets.

The horizontal and vertical angles of the jets should be adjusted to give the required width of trench and to cut off the face of the clay and not merely bore holes in it.

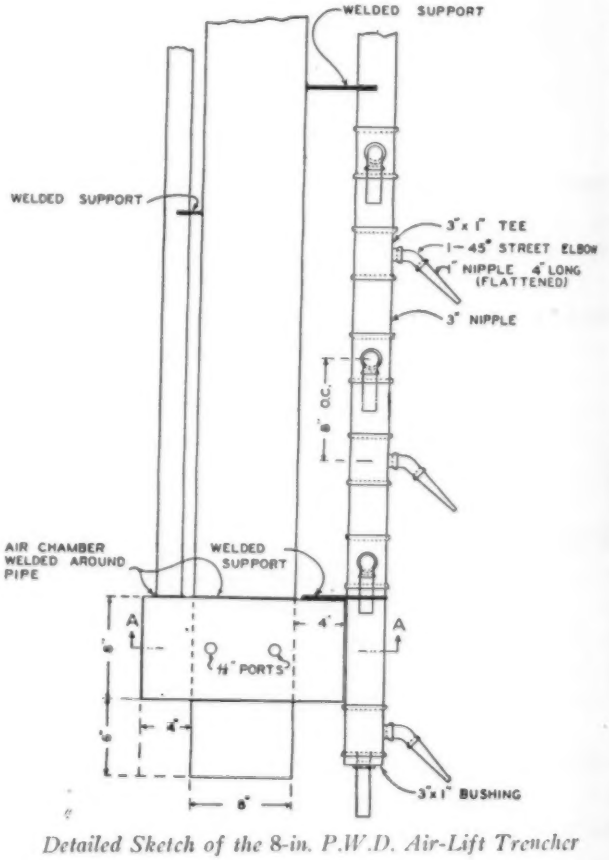
It was found to be helpful to keep the trencher constantly moving up and down a few inches. This was probably because the jets were some inches apart. The rate of trenching varied with the quality of the material. In medium soft clay the speed reached 25 feet per hour of actual digging and the trench on the harbor bottom was about three feet wide at the top.

It is believed that an air-lift device of this type will have a variety of uses in water and sewage works practice in addition to trenching. For instance, these units might be used for lifting (and at the same time washing) sand and small gravel. A small unit may be used for removing sand from rapid sand filters and transferring it from one unit to another. It could be used in excavating, desludging basins or lagoons.

In sewage it could be used to transfer sludge, lift and wash grit, de-sludge tanks or lagoons, and like uses. The units are readily portable, with a short riser and air pipe subject to extension to any desired length through use of plain end pipe lengths—and gasketted flexible couplings.



SECTION A–A



Detailed Sketch of the 8-in. P.W.D. Air-Lift Trencher

WATER REQUIREMENTS*

Volume Demand and Rates of Flow for Various Uses and Fixtures

Twenty gallons per capita daily is generally conceded to be the absolute minimum quantity of water needed to carry out, properly, the various functions of life of those served a supply of water piped into the property.

The basis for such a per user estimate is the following:

Drinking	1 gal.
Laundry	6 "
Bathing	5 "
Toilet (2 flushes)	5 "

(Possibly the item "Drinking" includes all water used in the kitchen. However, nothing is shown for scrubbing and other miscellaneous uses. So it is apparent that the average per user requirement should be at least 25 gallons and the *reasonable* minimum probably more nearly 30 gallons. In fact, surveys have revealed such to be the case.)

In a recent review of water consumption data the following procedure in estimating appears.*

"For purposes of estimating the probable use of water in a given building the engineer considers those quantities which are used for specific domestic operations and which do not vary appreciably with size of family, as well as the basic consumption rate of 20 gallons per capita per day. The total amount of water used in sprinkling a lawn does not vary with the number of persons living in a given house, nor does the quantity used for washing the family car. On the other hand, the use of water for personal bathing is directly related to the number of persons in the household.

"The figures which are presented here are subject to some variation but they may well serve as an index of the amounts which may reasonably be considered to be used in carrying out various domestic operations. Studies here and abroad have indicated that about one-half to two-thirds of the water used in ordinary household consumption is heated (bathing, laundering, dishwashing, etc.)."

Operation	*Quantity-of-Water*
Tub bath	25 gallons/bath
Shower bath	5 gallons/min.
Additional toilet flush/person	6 gallons/diem
Sprinkling lawn (⅝-inch hose)	7 gallons/min.
Washing automobile	150 gallons
Basic quantity/person	20 gallons/diem

"Two examples will illustrate the use of these data.

Example 1.—A family of five persons is to build a single house on a lot 50 by 100 ft. in a fairly good neighborhood. They plan to have a bathtub and do home laundering, but they have no automobile. How much water per capita (in round numbers) should be estimated as the daily consumption for this family

Basic figure $= 5 \times 20 = 100$ g.p.d.
Lawn watering = 20 min./diem for 3 mos. = 5 min./diem = 35 g.p.d.
Bathing—2 baths/week/person $= 5 \times 50/7 =$ 35 g.p.d.
Total = 170 g.p.d.
Per capita consumption = 34 g.p.d.

Example 2.—A family of three is to build a large house on a plot 125 by 250 ft. in an exclusive section of town. Laundering is to be done at home and the two cars probably will be washed twice a month at home. There is a shower for the head of the house, and two baths for the two women. What water consumption per capita could be estimated here?

Basic figure $= 3 \times 20 =$	60 g.p.d.
Additional toilet flushes, $3 \times 6 =$	18 g.p.d.
Lawn watering 1 hour/day for 4 mos. = 20 mins./day for the year =	140 g.p.d.
Bathing—2 baths/day =	50 g.p.d.
Showers—10 min./diem =	50 g.p.d.
Washing cars—600 gal./mo. =	20 g.p.d.
Total	326 g.p.d.
Per capita consumption	109 g.p.d.

*Based on data and computations in a review of water requirements in "Domestic Water Consumption" Jour. A.W.W.A., December, 1939—by M. A. Pond, and published information from various other sources.

Similar methods of approach may be used in solving problems involving large apartments and housing projects."—Jour. A.W.W.A.

In an analysis of available survey statistics from representative cities, essentially, the following conclusions appear in the same article.*

(1) The minimum domestic water requirements for an urban community or household should be assumed at not less than 30 gals./capita/day.

(2) For design of systems, service lines and interior piping it is safer practice in general to use a figure of 40 gals./capita/day.

(3) The increase in consumption can be estimated at a rate of 1% per year, until a maximum of 50 gals./capita/day is reached.

Water Requirements in Various Types of Housing

The following estimates of expected consumption in various types of housing are based on data presented in the same review.

Type of Housing	*Gal./Capita/Day*
Single Family Houses	
Minimum	35
Reasonable	55
Maximum	100+
2, 3 and 4 Family Houses	
Minimum	35
Average	40
Maximum	55
Apartment Houses	
Average	75
Maximum	100+
Housing Projects	
Minimum	35
Reasonable	45**
Maximum	90

RATES OF DRAFT PER FIXTURE OR USE

Individual Needs	Gallons per Day
For all household purposes, including kitchen, laundry, bath, etc.	30
Each cow	10
Each horse	10
Each hog	5
Each sheep	5
Continuous flowing drinking fountains	75

Lawn Fixtures	Gallons per Hour
½-inch hose with nozzle	200
¾-inch hose with nozzle	300
Lawn sprinkler	120
Park or golf course sprinkler covering a 106-ft. diameter area, with ¼-inch main nozzle operating at 50 lbs. nozzle pressure	990

Domestic Fixtures	Gallons
Filling the ordinary lavatory	1½
Filling the average bath tub	30
Flushing water cabinet closet	6
Shower bath	30

(*From, Peerless Pump Bulletin*)

**In measuring the proportion of total consumption that was used as heated water the average was 66%, or 28 gallons in the average total of 42 gallons used per head.

RATES OF FLOW FROM FIXTURES

Fixture	Gallons per Minute† Fair	Good	Excellent
Bath Tubs	5	18	10
Showers (5" to 8" heads)	3	6	8
Lavatory Basins	3	5	8
Laundry Tubs	4	8	10
Sinks (Kitchen & Pantry)	4	8	10
Hose (Sprinkling & Washing)	5	8	10
Toilet Flush (Tank)	2	3	5
Toilet Flush (Flushometer)	20	30	40

†Copper and Brass Research Association figures, supported by other data.

Expected Consumption Rates and Requisite Pipe Sizes in Apartment Buildings

The following tables taken from a bulletin of the Bridgeport Brass Co. indicate expected reasonable rates of draft by apartments of various sizes and number of baths. Also is listed the minimum sizes of service lines and recommended sizes of riser pipes, based on a pressure loss of 10 lbs./100 ft. of run, and terminal fixtures pressure of 15 lbs./sq./in. during water use in all apartments on the same riser, from top floor to ground.

TABLE 1.

RATES OF USE AND WATER SUPPLY RISERS FOR APARTMENT HOUSES

(Based Upon 1-2 & 3 Baths per Ap't.)

One (1) Bath Apartment		Two (2) Bath Apartment		Three (3) Bath Apartment	
1 bath	15 gals.	2 baths	24 gals.	3 baths	30 gals.
1 W. C.	8 gals.	2 W. C.	14 gals.	3 W. C.	18 gals.
1 sink	4 gals.	1 sink	4 gals.	1 sink	4 gals.
1 lav.	4 gals.	2 lavs.	6 gals.	3 lavs.	9 gals.
	31 gals.		48 gals.		61 gals.
60% demand, 15 gals. per min.		40%, 20 gals. per min.		40%, 24 gals. per min.	

		RISER		RISER		RISER
Top Floor	15 gals.	1¼"	20 gals.	1¼"	24 gals.	1¼"
Next	28 gals.	1¼"	38 gals.	1½"	43 gals.	2"
Next	38 gals.	1½"	54 gals.	2"	64 gals.	2"
Next	51 gals.	2"	68 gals.	2"	82 gals.	2"
Next	60 gals.	2"	80 gals.	2"	96 gals.	2½"
Next	67 gals.	2"	90 gals.	2"	108 gals.	2½"
Next	71 gals.	2"	98 gals.	2½"	117 gals.	2½"
Next	78 gals.	2"	104 gals.	2½"	124 gals.	2½"
Next	81 gals.	2"	108 gals.	2½"	134 gals.	2½"
Next	83 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	84 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	85 gals.	2"	110 gals.	2½"	143 gals.	2½"

TABLE 2.

APARTMENT HOUSE SUPPLY SIZES OF SERVICE LINES FROM MAIN

(Based on Pressure Loss of 10 lbs./100 ft. Run)

For 4 and 5 Stories

No. of Baths	APARTMENTS PER FLOOR: Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	120	2½"	160	3"	200	3"	240	3"
2 baths	160	3"	200	3"	240	3"	280	3"
3 baths	200	3"	240	3"	280	3"	320	3½"

For 6, 7 and 8 Stories

No. of Baths	APARTMENTS PER FLOOR: Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	150	2½"	190	3"	230	3"	270	3"
2 baths	190	3"	230	3"	270	3"	310	3½"
3 bath	230	3"	270	3"	310	3½"	350	3½"

For 9, 10, 11 and 12 Stories

No. of Baths	APARTMENTS PER FLOOR: Four Gals.	Four Main	Six Gals.	Six Main	Eight Gals.	Eight Main	Ten Gals.	Ten Main
1 bath	200	3"	250	3"	300	3½"	350	3½"
2 baths	250	3"	300	3½"	350	3½"	400	3½"
3 baths	300	3½"	350	3½"	400	3½"	450	4"

DELIVERY THROUGH BRASS AND COPPER PIPES OF VARIOUS SIZES FOR VARIOUS PRESSURE DROPS

(Each line being 100 ft. long)

Pressure Drop (Lbs.)	Gallons per Min. Delivery Through ⅜"	½"	¾"	1"	1½"	2"	2½"
5	2	3	7	13	40	80	150
10	3	5	10	20	60	130	225
20	4	7	15	30	90	200	300
30	5	9	20	40	120	250	375

BLOTTING OUT WASTE

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · but · ·
Don't Ignore Leaks!

* * *

Satisfied customers are worth more to us than revenue secured from water *uselessly* passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

COPPER SULPHATE

Some Aspects of Its Usefulness and Methods of Application

By PAUL WEIR, Supt. of Filtration
Atlanta, Georgia

THE utilitarian value of copper sulphate in the water purification plant has now come of age and it should be considered in the same light as other chemicals in the water treatment field. It should be applied by calibrated equipment of a permanent nature and not promiscuously fed through a dilapidated contraption. Proper equipment means effective and economical control.

Copper sulphate is essentially chemically pure, 25% of its weight being pure copper. It can be secured in a variety of crystal sizes from large lumps to fine powder. It is conveniently packaged in wooden barrels and 100-pound bags.

Copper is usually applied at two principal points in the purification process:

I. Open storage reservoirs.
II. In conjunction with other purification chemicals.

Methods of Application

Alone

The following four methods are most generally used in treating open storage reservoirs, depending upon their size, intensity of organism, propagation, and available equipment.

(a) Porous bag suspension.
(b) Perforated dispersion box or basket.
(c) Solution spray—(surface atomization).
(d) Pulverized crystal blower—(surface dusting).

One of the simplest methods of copper sulphate application consists in the placing of about 25 pounds of the crystals in burlap bags, or porous baskets, and attaching them to a boat, either astern or at the sides, so that they will drag in the water to be treated. Additional refills may be used as needed. It has been frequently suggested that the boat should follow a definite course, one series of parallel paths from 20 to 50 feet apart, and if the reservoir is deep, a second course should be made at right angles to the first in grid-iron formation.

Another method has been developed at Atlanta, whereby the shore line and areas too shallow for boat travel may be treated in an effective and economical manner. An inflated automobile inner tube is laced with rope or heavy twine, in a spider web or net effect. This floating basket supports a 25-pound bag of copper sulphate. A 25 to 50 foot sash cord, attached to the inner tube, permits a person to pull this device easily from the shore line. Atlanta has two raw water impounding reservoirs with a total surface area of 60 acres. Each reservoir has approximately 6,000 feet of shore line which requires 150 pounds of copper sulphate thus applied each month.

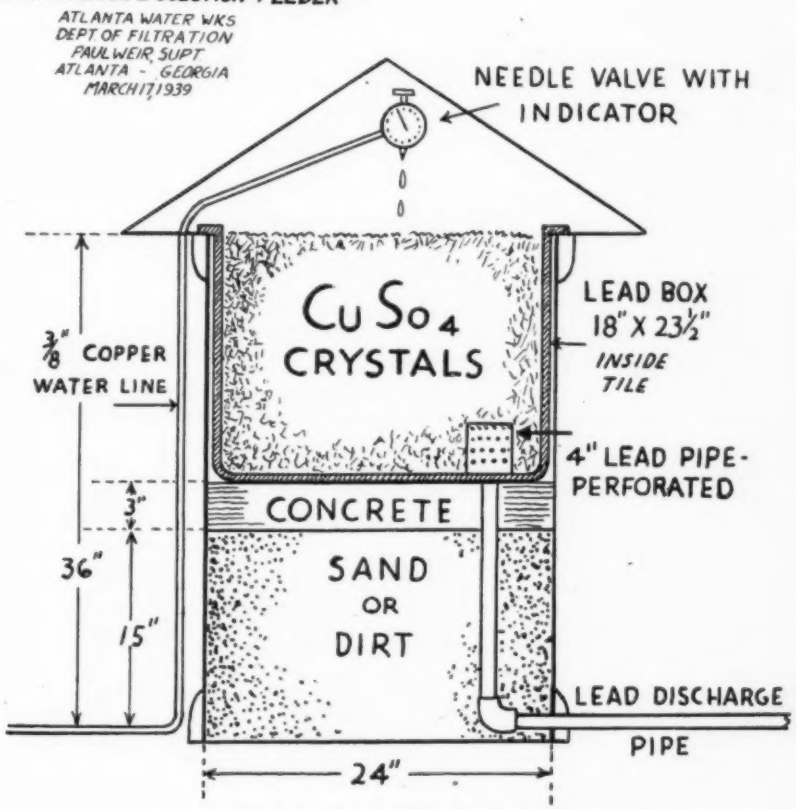
There are certain circumstances, however, that are not conducive to this simple method of treatment. It may be more expedient and economical, on the whole, to use the dispersion box and the spray or dry crystal blower methods of distribution.

With Other Chemicals

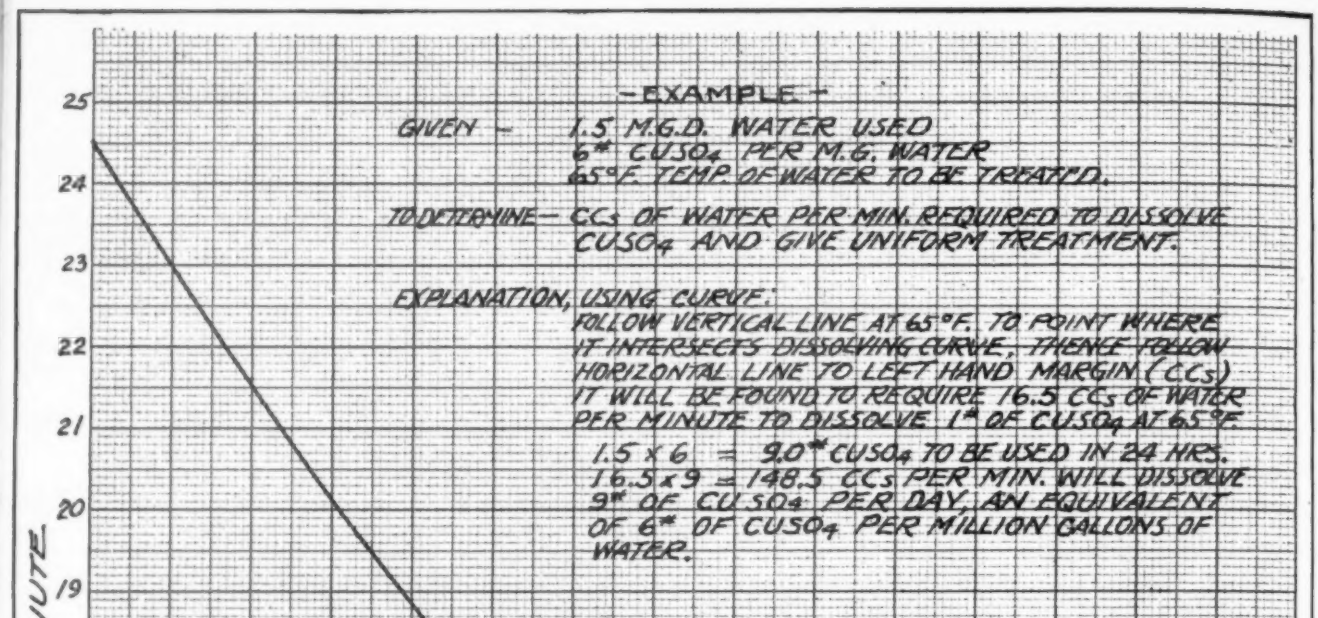
It has been frequently found necessary to apply copper sulphate continuously, at the inlet of the mixing chamber, or at other convenient points, during times when micro-organisms are most abundant and are not entirely reduced by reservoir treatment alone. This may be accomplished by making a concentrated solution in a paraffine-lined wooden barrel, or other acid resisting container. An orifice or stopcock drains the solution from the container into the water to be treated, necessitating recharging at frequent intervals. This type of equipment is usually a makeshift and is not conducive to uniform and economical feeding.

We at Atlanta have endeavored to make our copper feeding equipment permanent—(see illustrations). These feeders are of the solution type, and are mounted out-of-doors at the influent and effluent ends of the mixing chamber. A standard 3 foot length of 24 inch diameter terra cotta pipe is set in 4 inches of concrete grout, with the bell at the top. The lower 18 inches of this pipe is filled with sand and sealed with about 3 inches of concrete. Into the top 18 inches is fitted a circular lead container which rests upon the concrete slab. A heavy walled lead pipe of 1 in. diameter leads from the bottom of the circular lead container down and through the side of the terra cotta pipe and

One of the Atlanta Copper Sulphate Feeders
(Modified Shelton Design) Constructed by Atlanta Water Department (See detail sketch)



The Atlanta Copper Feed in Detail
(Note simplicity of construction and dosage control by needle-valve setting for water feed only)


- EXAMPLE -
GIVEN - 1.5 M.G.D. WATER USED
6# CUSO4 PER M.G. WATER
65°F. TEMP. OF WATER TO BE TREATED.
TO DETERMINE - CCs OF WATER PER MIN. REQUIRED TO DISSOLVE CUSO4 AND GIVE UNIFORM TREATMENT.
EXPLANATION, USING CURVE:
FOLLOW VERTICAL LINE AT 65°F. TO POINT WHERE IT INTERSECTS DISSOLVING CURVE, THENCE FOLLOW HORIZONTAL LINE TO LEFT HAND MARGIN (CCs) IT WILL BE FOUND TO REQUIRE 16.5 CCs OF WATER PER MINUTE TO DISSOLVE 1# OF CUSO4 AT 65°F.
1.5 x 6 = 9.0# CUSO4 TO BE USED IN 24 HRS.
16.5 x 9 = 148.5 CCs PER MIN. WILL DISSOLVE 9# OF CUSO4 PER DAY, AN EQUIVALENT OF 6# OF CUSO4 PER MILLION GALLONS OF WATER.
CCs WATER PER MINUTE
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
35° 40° 45° 50° 55° 60° 65° 70° 75° 80° 85° 90° 95° 100°
WATER TEMPERATURE - DEGREES FAHRENHEIT

Courtesy—Tennesse Copper Co., Copper Hill, Tennessee

From This Graph Is Determined the Rate of Water Feed Required to Dissolve and Feed the Desired Dosage of Copper Use of the graph in arriving at the correct water rate setting per pound of copper sulphate required per hour is explained on the graph. The solution discharged is saturated, varying in concentration with the temperature of feed water, consequently the need for water temperature readings and use of this helpful graph.

to the point of application. A small, circular, perforated lead baffle fits over the inlet to the feed line to prevent stoppage. Dry crystals (random size) are placed in the circular lead dissolving pot. Water from a ⅜-in. copper line flows through a pressure reducing valve, thence through a small orifice, where it drips into the copper crystals, forming a uniform saturated solution of copper sulphate. This flows out at the bottom of the pot. The quantity of copper sulphate is readily controlled by a calibrated needle valve, which admits the water through the orifice into the bed of copper crystals. The water flow is set in accordance with the temperature-solubility curve, here reproduced, so as to secure the desired rate of copper application.

An attractive metal mushroom-type cover protects the equipment from the elements. This apparatus is inexpensive to build, easy to operate, and is subject to accurate calibration to give the required dose. Its neat design makes it an asset to any plant. It will operate without adjustment for days, still maintaining the original setting and feed rate. One decided advantage, over many other types of home-made equipment, is that the control involves the feeding of nothing more difficult than pure water through the small orifice, rather than a corrosive or encrusting solution, as is usually the case with solution feed equipment. Small particles of foreign matter or undissolved crystals soon obstruct most any type of restricted orifice when employed in feeding copper sulphate solution.

Dissolving Water at Constant Temperature

It becomes apparent, from a study of the accompanying chart, employed in arriving at the flow rate for the dissolving water

stream in dosage manipulation, that if the supply of dissolving water could be produced at a constant temperature, or at a temperature which fluctuates but slightly, a worth while advantage accrues.

To attain such a desideratum, or an approach thereto, consideration of a scheme for producing a supply of water at ground water temperature, as developed in the Atlanta Water Department, is suggested. This scheme is an invention of Mr. William Rapp, Atlanta's late Superintendent of Construction and Distribution, which was first described and illustrated in detail in "Water Works and Sewerage." The descriptive article and drawing was reprinted on page 65 of the Data Section of the very useful April, 1939, issue.

In brief, the scheme consists of employing an existing well, or putting a new 4 inch well down into ground water to such a depth that a 5 foot long coil, made up of pure copper tubing, may be submerged in the ground water for the most part, if not completely so. The inlet (upper end) of the coil connects to a drop pipe from the city supply main. The outlet (lower end) discharges through a ⅜ in. riser of copper tube, running up alongside of or through the center of the coil. The city water supply will be cooled or warmed, as the case may be, to the rather constant temperature of the ground water which is constantly moving across non-pumped wells, or upwards through pumped wells. By this method, in Atlanta, water has been cooled and kept flowing under main pressure at 66 deg. F., although the city water entering Mr. Rapp's "ground cooler" has been as high as 87 deg. F. during the summer period.

In connection with the production and displacement of a saturated solution of a chemical in dosage control, the matter of *what* temperature is not the important consideration, but rather the production of a fairly *constant* temperature feed water, and knowledge of the concentration of saturated solution at such temperature. Naturally, some thought must at the same time be given to insulation of the dissolving pot in order that the chosen water temperature may be maintained fairly constant while passing through the saturation-pot.

We realize that there are other methods of producing water at thermostatically controlled temperatures, with constancy, but we rather enjoy the idea of letting Nature contribute its bit through use of the economical and fool-proof equipment and scheme of the eminently practical Mr. Rapp.

Effect of Copper Sulphate on Organisms

Microscopic examinations and threshold odor tests are important in attaining efficient application and control of copper sulphate treatment. There is not one fixed dosage of copper sulphate suitable for any one condition; but, generally speaking, an application of 2 to 10 pounds per million gallons of water will be found effective in the elimination of the most objectionable microscopic growths. And, continuous application of small doses usually gives good results in bringing about practical elimination of most of the more common and troublesome types. A twelve month program of application, on larger reservoirs, and early season control in mixing chamber, etc., makes possible the use of small applications and effects a maximum of organism reduction without taste and odor formation.

Copper sulphate should be used to *prevent* microscopic growths in a water purification system, rather than to kill the organisms after they have grown to large numbers. A small quantity of copper sulphate applied continuously during the growing season, or certainly at frequent intervals, will keep growths at a minimum and will also prove over-all a more economical procedure.

When it is convenient to lower the water line in a water treatment plant or dewater it entirely, algae adhering to the walls may be eliminated by spraying or washing the exposed area with a 5% solution of copper sulphate.

Filter Bed Clogging

A number of water plant operators have experienced a partial if not an almost complete clogging of filter beds by micro-organisms. Greatest relief has been had when copper sulphate treatment was begun and continuously applied during the propagation season. Diatoma and synedra are usually the chief offenders and may be killed, or reduced, by using approximately 2 to 6 pounds of $CuSO_4$ per million gallons of water.

At Spartanburg (1), Marquis describes a situation where a new plant was put into service, after the supply reservoir had been idle a long time, permitting a luxuriant growth of algae. Rapid sand filters became so densely matted with algae that filter runs were reduced to 1½ hours between washings. The wash water consumption reached 25% of the total pumpage and the city was on the verge of a water shortage. Copper sulphate was immediately applied to an area 1,000 feet in front of the raw-water intake by dragging copper sulphate crystals in a burlap bag fastened behind a boat. Approximately 13 pounds of $CuSO_4$ were used for each million gallons of water. This treatment was continued daily until relief was apparent at the filter plant. After the initial emergency was over, copper sulphate was regularly applied by solution feed at the inlet of the mixing chamber. Dosages ranged from 2 to 13 pounds per million gallons. This same procedure has been followed yearly since, without similar reoccurrence.

A few years ago, Atlanta experienced the formation of troublesome sheets of microorganisms, in the impounding reservoirs, which reduced filter runs from 120 hours to 20 hours between washings. Taste and odor complaints ensued. This was rectified by monthly applications of $CuSO_4$, at the edge of the reservoir and also continuous application at the inlet of the mixing chamber, when the raw water turbidity drops below 25 p.p.m. At such times 2 to 7 pounds of $CuSO_4$ per million gallons of water are used to combat these growths, with satisfactory results. The continuous application of 4 pounds of copper sulphate per million at Atlanta, during periods of algae propagation, has materially reduced tastes and odors, chlorine consuming substances, and coagulant used. This results in a more palatable drinking water, at a reasonable cost, and filter runs at Atlanta are almost directly proportionl to the concentration of micro-organisms in the *applied* water.

The Question of Copper on Health

It is believed that the judicious use of copper sulphate to prevent and kill algae in water purification systems is not harmful to health and is sanctioned by practically every State Department of Health in the U. S. A. (2).

Reliable authorities (3) have more recently proven that doses of $CuSO_4$, as high as 100 pounds per million gallons, could be used with alum coagulation, if the pH of the water is above 6.3, without danger of copper passing the filters.

Negus (4) states that it is necessary for about 30 p.p.m. of copper ions (120 p.p.m. of copper sulphate) to be present in water to stain white plumbing fixtures. He further states that research and experience have proven that a copper limit of 0.2 p.p.m. (about one-half the amount present in cow's milk) is much lower than necessary. Conservatively, five times this amount (1.0 p.p.m.) would still be considered safe.

Uses Other than as an Algaecide

Copper sulphate is said to increase the toxicity of ammonia-chlorine sterilization under certain conditions.

At Indianapolis the combination of pre-chlorination and copper sulphate has proved highly effective.

Copper sulphate has been successfully used, with aluminum sulphate, to control algae growths on the vertical side walls of reservoirs and basins. Eight to 16 pounds per million gallons of copper sulphate proved satisfactory in this undertaking (5).

Copper salts are highly effective coagulants and Damn and Bock (6) report that when milk waste was treated with two pounds of copper sulphate to between 225 and 275 cu. ft. of waste a good floc was produced. A clear effluent was obtained by passing the flocculated material through a magnetite filter. The precipitated sludge is said to have possibilities as a fertilizer.

Conclusions

Fundamentally, all structures entering into the storage, purification, and distribution of water supplies should be maintained in a high degree of cleanliness, free from slimes, growths and deposits. Treatment with copper sulphate continuously, where possible, or intermittently where absolutely necessary due to local conditions, accomplishes this.

Experience in many plants shows that copper sulphate contributes to better operation not only through algae control but betterment of plant operation by its effect upon floc, filter condition, and appearance of finished water.

During 40 years of usage copper sulphate has demonstrated its indispensability in water treatment and deserves regard as one of our most important water purification chemicals.

Like the famed "ounce of prevention," a pound of copper effectively timed and placed is worth more than "tons" of regrets and explanations.

References

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INFILCO INC.

Water Conditioning, Sewage Treating, Hydraulic Control and Chemical Feed Equipment

325 W. 25TH PLACE, CHICAGO 16, ILL.

PRODUCTS

ACCELATORS—Clarifying, softening and stabilizing
AERATORS—Multi-Cone, forced draft, coke tray and cascade; floating and adjustable cone aerator nozzles
BOILER FEED WATER TREATMENT PLANTS—Softener and silica removal
CARBON (Activated) PURIFIERS—Taste, odor and color removal plants
CHEMICAL FEEDERS—Dry and solution types, combination mixers and feeders
COLOR REMOVAL PLANTS
CONTROLLERS—Chemical feed, rate of flow, liquid level and hydraulic valve
DEMINERALIZATION PLANTS FOR WATER AND SUGAR
FILTERS—Concrete and wood gravity, pressure and disk type water filters; also oil removal, swimming pool, etc.
FILTER PLANT EQUIPMENT—Controls, gauges, flow meters, indicators, recorders, operating tables, transfer switches, etc.
GAUGES—Rate of flow, loss of head, liquid level, etc.
ION EXCHANGER PLANTS
LIME FEEDERS AND SLAKERS
SEWAGE TREATING EQUIPMENT—Accelo-Biox, Accelo-Filter, activators, coagulators, clarifiers, dosing siphons, rotary distributors, samplers
SOFTENING PLANTS—Lime-Soda, Hot-Flow, Accelator and Zeolite (green sand, synthetic gel, carbonaceous and resinous)
STERILIZING EQUIPMENT
SWIMMING POOL EQUIPMENT—Gravity and pressure filters, cleaners, fittings, etc.
TASTE AND ODOR REMOVAL PLANTS
VENTURI TUBES
WATER FILTERS AND FILTER PLANT EQUIPMENT
WATER SOFTENING PLANTS OF ALL TYPES
ZEOLITES AND ZEOLITE WATER SOFTENERS

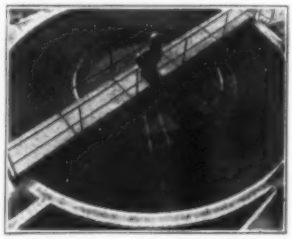
WATER CONDITIONING EQUIPMENT

INFILCO SERVICES

INFILCO has specialized in the design and manufacture of all kinds of water conditioning equipment—from Accelators to Zeolites—for over forty years.

The consulting engineer or his client can specify "Infilco" throughout the water treating plant knowing that such equipment has the benefit of Infilco's vast experience in supplying thousands of installations. Specifying one brand of equipment throughout gives the added assurance of undivided responsibility and coordinated results. The services of Infilco's staff of competent engineers and their complete laboratory facilities, ready to cooperate in making recommendations and reports, are at the disposal of the consulting engineer or his client.

ACCELATOR SOFTENERS AND CLARIFIERS

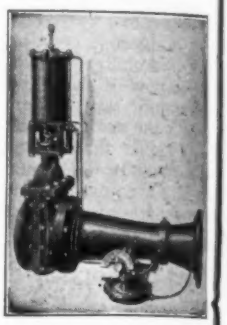


The Accelator for water softening and clarifying is one of the most important water treating developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

ZEOLITES AND ZEOLITE SOFTENERS

Infilco Zeolite Softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic or full automatic operation as desired. A variety of Infilco Zeolites are available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco Zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.

CONTROLLERS AND GAUGES



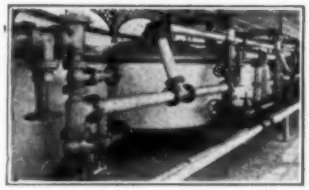
Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity type filter plants, in capacities from a hundred gallons per day up.

The design of every Infilco filter plant is based upon sound engineering principles, backed by over four decades of experience in equipping many hundred municipal water works, and building tens of thousands of industrial filters.



RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

COAGULATORS

Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

TRANSFER SWITCHES, OPERATING TABLES ROBOTROLS AND SAMPLING TABLES

Infilco Transfer Switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco Operating Tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

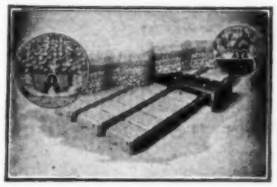
The Robotrol is a robot filter, or softener, operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently and without supervision.

Sampling tables furnish a visual check on the condition of raw, settled and filtered water.

HYDRODARCO PURIFIERS

Hydrodarco is the activated carbon made expressly for water purification. Hydrodarco Purifiers, employing beds of granular Hydrodarco, automatically remove tastes, odors, chlorine, iron, organic color, etc. They are furnished in capacities from a few gallons per hour to millions of gallons per day.

INFILCO FILTER UNDERDRAINS



Wagner Filter Underdrains provide a primary distributing system of a manifold and laterals on wide centers, with distributing orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

FLUOREX PURIFIERS

Fluorex is a specially prepared, highly porous and reactive tricalcium phosphate for removing fluorine from water. Fluorex Purifiers, with their improved method of regeneration which prolongs the active life of the adsorbant and makes possible the use of ordinary materials and construction, offer the ideal means of removing fluorine.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

SEWAGE TREATING EQUIPMENT

INFILCO manufactures equipment for all sewage treating processes—chemical, biological and mechanical. In offering many products for application in these various processes, Infilco also offers the user the advantage of centralized responsibility, which is important in assuring continued satisfactory equipment operation.

ACCELO BIOX PROCESS

Accelo Biox is Infilco's name for a high rate activated sludge process involving direct recirculation of aeration tank mixed liquor. This process is producing results comparable to those obtained in any conventional activated sludge plant and it employs only half the aeration tank volume and blower capacity. The resulting savings in initial investment and operating cost are readily apparent. Designs embodying the Accelo Biox Process are available for any sized plant.

ACCELO-FILTER SYSTEMS

The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.

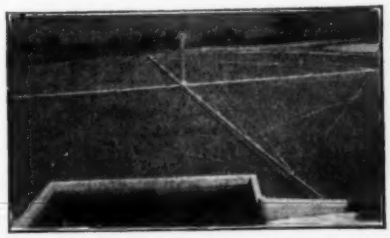
Aero-Spray Nozzles on a rotary distributor (above) provide a fan-shaped variable spray which assures optimum coverage and maximum aeration in the application of screened, settled sewage to trickling filters. All parts of these improved nozzles are bronze to assure long life.

CLARIFIERS

Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation of a sewage concentrator. These Clarifiers are designed with curved rotating scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

The two different sizes of Infilco Clarifiers assure effective removal of solids from the sedimentation tank whether it be small or large. The WS Clarifier with central motor reducer drive is supplied for tank diameters up to 40 feet. For diameters larger than 40 feet, there is the PD Clarifier, driven by a horizontal motorized reducer through a pinion which meshes with a stationary rack at the tank periphery.

ROTARY DISTRIBUTORS AND DOSING SIPHONS



Only Infilco Rotary Distributors offer so many important refinements such as full-opening arm end gates, mercury seal with protective seal ring, and corrosion-resistant nickel iron castings, along with low operating head requirements and uniformity of distribution. Infilco dosing siphons insure perfect operation of distribution mechanism at all flow rates.

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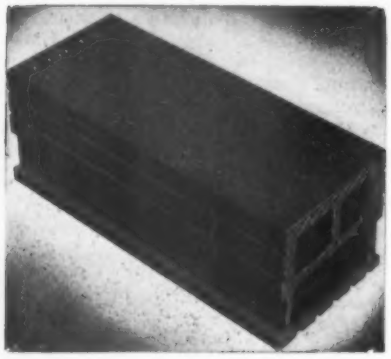

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The Compound Duplex Filter Bottom is now produced from high grade, de-aired fire clay, vitrified and salt glazed.

This design is not just something new but a tested and approved system operating in many plants.

The Leopold Filter Bottom cannot be compared with any other type of filter under-drain system as it is entirely different and eliminates all the difficulties experienced with other types. Each block is a separate collecting and distributing unit of 2 sq. ft. of filter area and assures a positive and equal collection of filtered water and distribution of wash water.

The large gravel bed is eliminated, thus removing the source of most filter troubles.

The Low Loss of Head through this system (less than 1.50 ft.) at the normal back wash rate, reduces pipe and valve sizes, making possible a great economy in piping design.

Filter Blocks are made in various lengths, making this system adaptable to all sizes of old or new rectangular filter beds.

For rebuilding your old filters our large stock of material makes prompt shipment possible.

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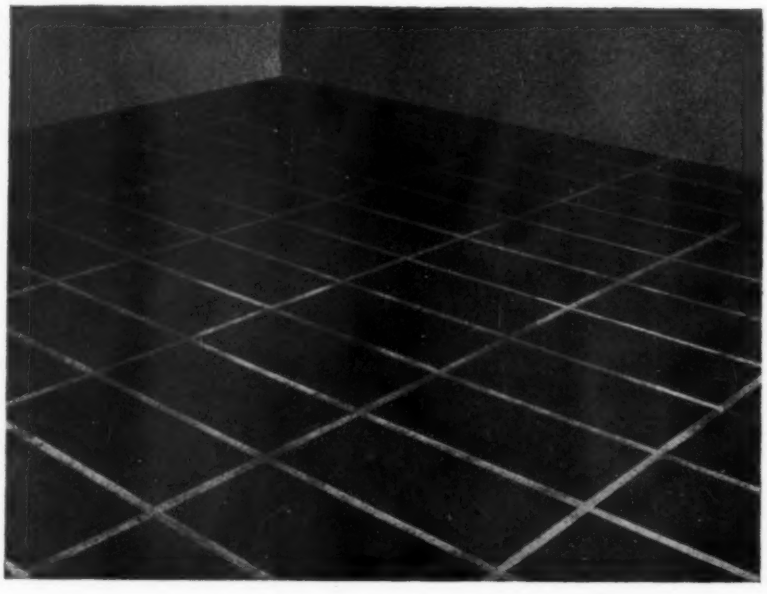
Also Leopold Filter Operating Tables, Chemical Feeders, Agitators, Aerators, Samplers, Pressure Filters, etc.

Facilities for furnishing Complete Treatment Plant Equipment.



Section of Completed Filter

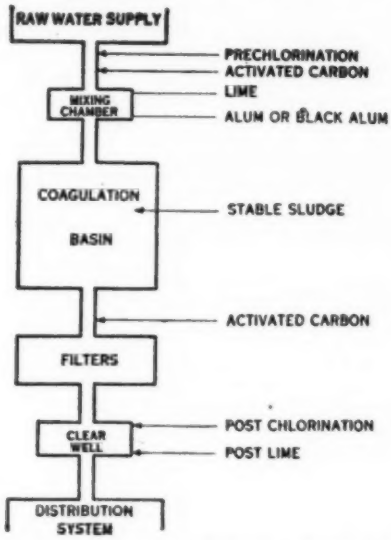
TASTE AND ODOR CONTROL WITH ACTIVATED CARBON

By E. A. SIGWORTH

Manager, Water Purification Dept., Industrial Chemical Sales Div., West Virginia Pulp and Paper Co., New York, N. Y.

ACTIVATED Carbon is a form of charcoal and, as used in water purification, is a very fine powder, or granular product. Since the finely powdered form is that most frequently used in water purification, the granular form will be eliminated from further consideration in this test.

Activated Carbon may resemble in appearance that of many other forms of carbon including charcoal, gas carbon black, etc. Therefore, it is not possible by a cursory examination to distinguish between an activated and an unactivated carbon. The true measure of an activated carbon is what it accomplishes in purification, and in the case of water purification this means its ability to remove odors and tastes. This removal is accomplished by concentration of impurities on the surfaces of the carbon particles. Thus an Activated Carbon may be considered as particles of carbon having a tremendous internal and external surface area which has been so purified as to eliminate any foreign materials clinging to the surface.



Flow Sheet for Chlorine and Activated Carbon Applications

Activated Carbons work by the physical phenomenon known as adsorption. By adsorption we mean the selective removal of materials from a solution, such as cloth picking up color from a solution when a dress is dyed. This should be distinguished from absorption such as is accomplished when water is soaked up by a sponge.

Methods of Application

Activated Carbon is usually applied continuously to a supply as the water passes through the purification system. In order to accomplish this, various proportioning devices of both dry and solution-type feeding have been employed successfully. Either solution or dry feeding equipment can be designed with sufficient accuracy to meet requirements in the water works field. The particular type of equipment to be employed for feeding depends upon the plant set-up, and individual preference. The dry feeding type of equipment is most frequently used because it involves less labor in feeding and control of the dosage. Many manufacturers have placed on the market feeding equipment specially designed for feeding activated carbon. It is suggested, however, that before purchase, the types of equipment be studied closely from the viewpoint of performance under all operating conditions.

Points of Application

Activated Carbon is insoluble and when added to water gives a black appearance. It is therefore evident that the carbon must be removed from the water before it enters the distribution system. Thus, carbon is usually applied ahead of sand filters. In normal water purification systems the points where carbon will logically be applied are; in the raw water, to the mixing basin, to the settling basin, or to the filters. Surveys have shown that the most common point of application for activated carbon is to the mixing basin, although each specific point of application has certain inherent advantages which must be taken into consideration in attempting to determine that point where best results will be accomplished. Furthermore, certain limitations may exist within individual plants preventing application at the point where best results might be expected.

First consideration must be given, therefore, to the specific design of the purification plant and a decision reached as to which points might be employed for the application. Factors which will play a part in such decisions are the degree of mixing of carbon with the water, and the mechanical design of the purification system. Carbon should not be applied where the water is in a relatively quiescent state since it will not disperse sufficiently to give contact throughout the entire body of water. Therefore, carbon should be applied at points where there is a restricted flow of water such as in mixing basins, near baffles in the settling basin, or to the filter influent.

Any point of application of carbon, whether before or after coagulation, has some advantages, and disadvantages. For example, where carbon is applied before coagulation, high dosages can be applied in order to take care of highly concentrated odors in a water supply. On the other hand, application of high dosages of carbon after coagulation might adversely affect the length of filter runs. Activated carbon when applied prior to coagulation partially settles out with the floc, resulting in a stabilizing action in the basins, thus decreasing the possibility of the water picking up odors due to decomposition within the water purification plant. Application of activated carbon to the filters is advantageous where odors have increased so suddenly as to get through the plant before they are noticed. Thus, application to the filters may save several hours of valuable time in controlling the odors. Furthermore, application in filters has been reported to be more economical because the odors at that point are less concentrated as a result of the effect of previous treatments.

There are so many inherent advantages to the various specific points of application that some operators have adopted the policy of applying carbon as a split treatment, part being applied to the water prior to coagulation and the remainder to the water after coagulation.

Effect of Other Chemicals

In any severe taste and odor problem it is advisable to consider the effect of other chemicals in order to determine the point of application of activated carbon which will accomplish maximum results. Because the effect of chemical treatment will vary quite appreciably within different plants, it is desirable that a study be made within the individual plant. Thus, any comments which we may make regarding the effect of other chemical treatments on odors must be considered as somewhat generalized statements. Aeration will normally accomplish an odor reduction of 10-15%, depending upon the efficiency of the aeration equipment and the concentration and type of odors. Coagulation appears to be a variable factor, since odors are sometimes increased and at other times are decreased. Actual experiences in plant operation are rather difficult to obtain because of the influence of activated carbon being utilized in the mixing basin. However, generally speaking it appears that coagulation does, in general, reduce odors to some slight extent, perhaps 5-10 percent. Filtration is also a rather questionable factor because of the influence of carbon within the treatment plant. As in the case of coagulation, the effect of filtration on odor is quite variable, reduction being very pronounced in some cases but slight in others. Perhaps a general all-around figure for the efficiency of filtration in reducing odors is approximately 10 percent. Thus the cumulative effect of various treatments of chemicals is relatively minor and cannot normally be considered as sufficient to correct a taste and odor condition in a water supply.

Dosages and Cost of Activated Carbon Treatment

Tastes and odors likely to be encountered in a water supply vary considerably. This can be readily understood when it is realized that tastes and odors may be caused by algae, decomposing vegetation, leaves, trade wastes, etc. In the case of algae alone, each of the many varieties frequently occurring in water supplies will give rise to odors peculiar to the specific type of algae.

Since these many odors are absorbed in different degrees by activated carbon, it is impossible to predict the dosage necessary. Furthermore, some odors are much more objectionable than others, even at extremely low concentrations. Cases have been reported where threshold odors as high as 30 have been considered palatable. Yet in one exceptional case many consumer complaints resulted from delivering water having a threshold odor of 2. In order to eliminate these complaints, it was eventually necessary to bring the threshhold odor on the delivered water to a value below 1.5.

Thus, in order to determine the carbonate dosage, it is first necessary to determine the extent to which the odor must be removed in order to render the water palatable. Following this, the carbon dosage necessary to accomplish the desired removal can be determined by employing various amounts in laboratory or plant scale tests. The average dosage of carbon being applied for eliminating tastes and odors will usually range from 20-40 lbs. per million gallons. However, as explained above, this should be considered as only an average figure since lower or appreciably higher dosages may be necessary. To give some idea of the different dosages necessary, let us consider two specific cases. In one water plant in the Mid-West it has been found that with threshold odors of 100 it is necessary to apply approximately 800 lbs. of activated carbon per million gallons in order to deliver a palatable water. In another plant in the Eastern part of the United States, actual experience demonstrated that with a threshold odor of 80 in the raw water a carbon dosage of 25 lbs. per million gallons resulted in delivering a palatable water to the consumer.

The actual cost of treatment is, necessarily, a variable factor, depending upon the quantity of carbon necessary. However, it is desirable that costs of treatment should be calculated on an annual basis rather than on periodic intervals when a severe taste and odor epidemic may occur. If calculations are on an annual basis it will be realized that periods of high carbon dosages will be offset by those periods when extremely small proportions are necessary. Therefore, on an annual basis it has been estimated that the average cost of activated carbon for taste and odor control would represent only approximately 3c per capita per year. Certainly such a low cost for delivering palatable water should be no hardship on any community.

Applications to Reservoirs

Thus far, consideration has been given to the use of activated carbon where sand filters are available for removal of activated carbon and adsorbed impurities. Many water systems, throughout the country, having no sand filters, are occasionally faced with taste and odor problems and, in a number of cases, activated carbon has been applied directly to reservoirs.

Where carbon is applied to reservoirs, provision should be made for a sufficient settling period in order to eliminate any appreciable quantity of activated carbon entering the distribution system. Therefore, where possible the reservoir should be taken out of service for two or three days in order to allow the carbon particles to settle to the bottom. In some cases it has been impossible to take reservoirs out of service, even for short periods of time, and in such cases activated carbon has been applied, taking care that the application is not made too close to the outlet gate.

The dosage of carbon applied to reservoirs is usually kept rather low, utilizing from 10-20 lbs. of activated carbon per million gallons of water in the reservoir. If this dosage does not render the water palatable, further treatment can be made after a week or two. Utilizing successive treatments for a reservoir has many advantages. In the first place, in the event any carbon does not get out into the distribution system small dosages will not be noticeable. Furthermore, from the labor point of view it is seasier to handle the smaller amounts of carbon utilized in the stage treatments.

In applying activated carbon to a reservoir, it is desirable to wet the carbon thoroughly before application since carbon particles have a tendency to float upon the surface of the water. The recommended procedure is that followed by Marshall S. Wellington in treating the Beaver Brook Reservoir at New Haven, Connecticut. He has described the method employed as follows:

> "Two one inch holes were bored on opposite sides of a fifty gallon barrel near the bottom. Glass tubing with an inside diameter of an ordinary pencil was inserted in the rubber stoppers and the stoppers in their turn inserted in the holes in the barrel. Small stoppers were then inserted in the other ends of the pieces of glass tubing. The barrel was then placed on the stern of a boat. This allowed the outlet ends of the glass tubing to remain about four inches above the surface of the water. The man power was distributed as follows: One man to add the activated carbon to the barrel and to keep it agitated. The second man to row the boat. The third man in the bow of the boat with a hydrant pump to keep a supply of water from the lake going into the barrel. The outlets on the glass tubes were made the proper size so that the man could keep the barrel full and yet not be overworked.
>
> "The carbon was mixed in a heavy soupy mixture in the barrel at the start, and when the boat arrived at the place to start treatment the small stoppers were removed and the mixture allowed to run out. The man at the barrel added fresh carbon when the mixture became too thin, while the man with the pump kept the barrel full. The boat was rowed in a similar manner as when Copper Sulfate was applied. This method allowed the carbon to be added in a continuous manner at a very fast rate. A very noticeable feature of this method was the fact that the mixture flowing from the glass tubes penetrated under the surface of the water before it started to spread. After the addition of the carbon was completed there was very little floating on the surface of the water."

Application of activated carbon to a reservoir in sufficient quantity to control tastes and odors appears to have quite a lasting effect as evidenced by the fact that treatment is usually not necessary for a period of two or more years. This may be due to the film of carbon which has formed on the bottom of the reservoir. Experiences in water purification plants have demonstrated the stabilizing influence of activated carbon on sludge decomposition and it is quite possible that the carbon on the bottom of the reservoir is exerting a similar influence. There is also a possibility that the black carbon film may have some tendency to discourage certain types of algae growths.

Although the original cost for treatment of a reservoir with activated carbon may be considered somewhat high, the possible extended influence of the carbon for long periods of time should demonstrate definite economy for this method of carbon treatment.

Blackout of Algae

The first application of activated carbon for algae blackout is credited to William P. Bailey at the City Water Works, Council Bluffs, Iowa. Although the successful use of activated carbon for algae control in settling basins was discovered by Mr. Bailey many years ago, it has only been recently that other plants have adopted this application. At the Council Bluffs plant, activated carbon was applied, not only to control algae, but also to remove odors. The amount of activated carbon necessary for taste and odor control was ample to accomplish algae blackout, consequently the most economical carbon dosage necessary to accomplish this blackout was not determined. It remained for Hartung and Lischer, St. Louis County Water Dept., St. Louis, Missouri, to determine the dosage of carbon necessary to treat a particular area of settling basins. At the St. Louis County Water Company plant, it was found that algae could be controlled at a dosage of approximately ¼ lb. per thousand square feet of area. Records reported by Bailey on operations at Council Bluffs, Iowa, show that the average carbon dosage was 1.47 pounds per thousand square feet. It should be realized, however, that this latter dosage was utilized to accomplish taste and odor control as well as algae blackout.

The method of application of activated carbon for algae control is somewhat similar to that recommended for reservoir application. The carbon is thoroughly wet and distributed over the surface of the basin once or twice a day. Since carbon is applied to exclude sunlight, it will be realized that application is not essential on cloudy days. Further details in the use of activated carbon for algae blackout are contained in a booklet entitled "TASTE AND ODOR CONTROL IN WATER PURIFICATION"*

*Gratis copies available from Industrial Chemical Sales Division, West Virginia Pulp & Paper Company, 230 Park Avenue, New York, N. Y.

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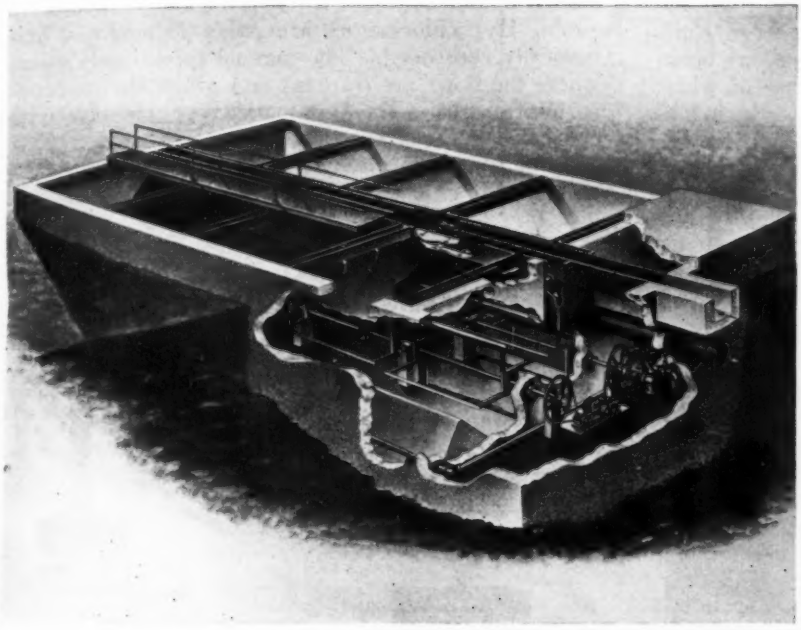

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This revolutionary new equipment removes hardness and suspended solids in a much shorter detention period, saves chemicals, takes only half the space of old-type plants. The raw water and chemicals are mixed in a compartment where they are agitated with the suspended sludge from previously treated water. This speeds precipitation. The water and precipitates then pass into the filter upflow compartment which has a gradually increasing cross-section. The gradually reduced velocity of upflow supports the sludge filter at uniform density throughout the filtering zone. A rate of flow is reached at which the sludge is no longer supported, but drops sharply out. The effluent is clear, and may not need further filtration.

Permutit makes every type and size of water conditioning equipment. Here are a few:

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In Permutit's pressure zeolite softeners, a single multi-port valve, operated automatically or manually, conducts the raw water into a shell, distributes it evenly through a bed of zeolite and collects it, the water flowing to service completely softened. The valve also controls backwashing to clean the bed, regeneration with brine, and rinsing. Gravity zeolite units are also available.

PERMUTIT'S SPIRACTOR

The new cold lime soda water softener based on "catalytic precipitation" principle. Soft water in 8 minutes . . . no settling or sludge . . . Saves space and time.

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Produces a water practically free of all salts, at a fraction of the cost of distillation.

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Automatic and manual, gravity and pressure.

IRON REMOVAL FILTERS

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330 West 42nd St. New York 18, N. Y.

WATER CONDITIONING HEADQUARTERS

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus,
Dry Chemical Feed Devices, Etc.
Newark 1, New Jersey

"THE ONLY SAFE WATER IS A STERILIZED WATER"

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Albany	Chicago	Greensboro	Lexington	Pittsburgh	Seattle
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BREAK-POINT CHLORINATION

Recent developments in water works practice show that bacteria practically cease to exist where Break-Point Chlorination residuals are maintained. This is because the process assures the production of free available chlorine residuals which have a high killing potential. Involving the application of considerably larger quantities of chlorine than have heretofore been considered standard practice, this new technique has been developed through an increased understanding of what takes place when chlorine is added to water. In many plants, bacterial control by Break-Point Chlorination has been augmented with additional benefits such as vastly increased length of filter runs, improved color and enhanced plant capacity.

TYPE MASV AUTOMATIC SOLUTION FEED VISIBLE VACUUM CHLORINATOR

Where unusual or extreme fluctuations in water or sewage flow are to be chlorinated, the MASV type meets the requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator—rugged construction, simplicity of operation and low maintenance costs.

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THE W&T HYPOCHLORINATOR

W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochloride in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Water Operated Hypochlorinators are either manually or automatically controlled. The manual type is only suitable where the flows are constant and where electric current is unavailable. The automatic type proportions the chlorine solution to the flow of water and is especially adapted for small gravity water supplies with wide variations in flow.

TYPE MDPA DIRECT FEED AMMONIATOR

A self-contained unit specially adapted to handling ammonia gas, embodying the same sound principles of design and construction exemplified in W&T chlorinators. Rugged, accurate and dependable.

Type MDPA Ammoniator

W&T Dry Chemical Feeder

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF, and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

CONVENIENCE

W&T is represented in each of the 34 cities listed on Page 236 by a staff of chlorination specialists to assist in selecting proper equipment for any chlorination problem. Their recommendations involve no obligation.

Current literature on the many phases of chlorination, ammoniation and dry chemical feed is available on request.

CHLORINE DIOXIDE TREATMENT OF WATER

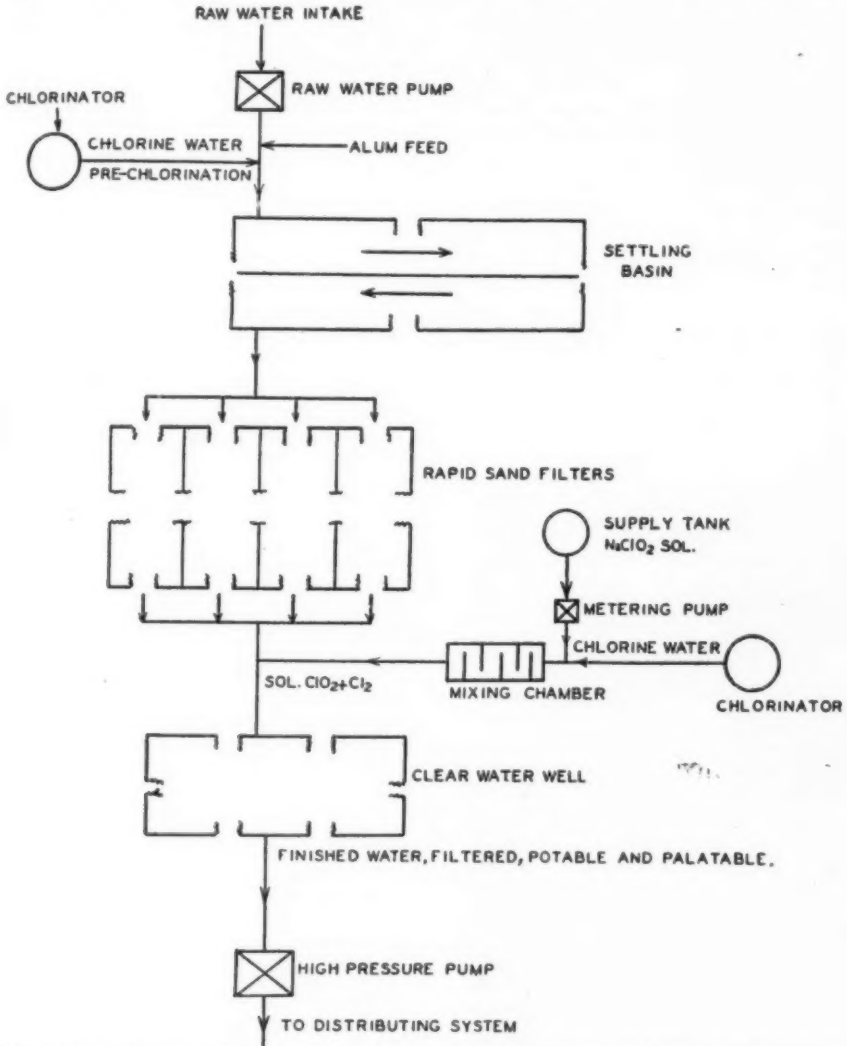
By JOHN F. SYNAN, J. D. MacMAHON and G. P. VINCENT

The Mathieson Alkali Works (Inc.), New York, N. Y.

THE chemical purification of public water supplies in this country is hardly forty years old. In this time, the use of chlorine gas or of hypochlorites in water treatment has become standard practice throughout the United States.

Now an even more effective water treatment has become possible, utilizing the powerful oxidizing gas, chlorine dioxide, ClO_2.

Chlorine dioxide, because of its instability, cannot be produced in bulk and stored until wanted. It must be generated in very low concentrations at the point of use, and consumed immediately. This was not feasible until recently, chiefly because of the difficulties inherent in the accepted method of generating the gas by reacting potassium chlorate with sulfuric acid. This method is low in production efficiency, does not give a pure product, gives rise to serious corrosion troubles, and is difficult to control.



Flow Sheet Showing Chlorine Dioxide Treatment of Water Supplies for Removal of Tastes and Odors.

A new source of chlorine dioxide was made available a few years ago when sodium chlorite, $NaClO_2$ was introduced commercially. Pure sodium chlorite is a white powder, stable both in the solid state and in solution. It is intermediate in properties between hypochlorite and chlorate, and contains 158 per cent available chlorine.† The commercial product is flaked and contains approximately 75 per cent chlorite.

Methods of Preparing ClO_2

Several methods have been developed to prepare chlorine dioxide from sodium chlorite. The earliest of these was an electrolytic method[1] based on the reaction.

$$2NaCl + 2NaClO_2 + 2H_2O \xrightarrow{2\ \text{Faradays}} 2ClO_2 + 2NaCl + NaOH + H_2$$

This process produces chlorine dioxide under satisfactory conditions for certain uses,[2] but requires complicated equipment. It was therefor abandoned when simpler and purely chemical processes were introduced.

The first of these chemical processes[3] was based on the fact that when chlorine is introduced into a solution of sodium chlorite, the following over-all reaction takes place at room temperature:

$$2\ NaClO_2 + Cl_2 \longrightarrow 2\ NaCl + 2ClO_2$$

This process, utilizing suitable control, measuring, and safety devices, is practicable.

Recently a method of generating chlorine dioxide by treating dry sodium chlorite with chlorine has been developed.[4] A mixture of chlorine and air is passed through two towers lined with stoneware and filled with flaked sodium chlorite. Chlorine dioxide is formed in accordance with the above reaction. Control of air and chlorine supplies regulates the amount of chlorine dioxide formed.[5]

For many processes the dry method is superior to the wet process. In the treatment of water supplies, however, the wet method is more applicable. The most practical method for generating chlorine dioxide for water treatment consists in feeding a sodium chlorite solution into the discharge line of a Wallace & Tiernan chlorinator and passing the solution through a mixing chamber to complete the reaction.

Properties of Chlorine Dioxide

At ordinary temperatures and pressures, chlorine dioxide is a yellow to red, unpleasant smelling, irritating gas, with a vapor density of approximately 2.4. The odor of chlorine dioxide is evident at 14 to 17 ppm. and at 45 ppm. it is irritating.

At room temperatures it is soluble in water to the extent of 2.9 grams of chlorine dioxide per liter at 30 mm. partial pressure. Its aqueous solutions are decomposed by light.

†Ed. Note. The term "available chlorine" is a misnomer. It is based on a fallacious concept that the concentration of chlorine in a hypochlorite solution is measured by the amount of iodine it will displace from a solution of potassium iodide, i.e., on the basis that one atom of chlorine will displace one atom of iodine. Actually one molecule of calcium hypochlorite, which contains but two atoms of chlorine will liberate four atoms of iodine from potassium iodide. The term "available chlorine" is therefore a measure of the total oxidizing power of the substance being tested and is twice the active chlorine value by weight. "Available chlorine" is determined by titrating the iodine released by the hypochlorite from an acidic solution of potassium iodide and is calculated as per cent by weight of the original hypochlorite.

Some calculated theoretical "available chlorine" contents of various hypochlorites are shown in the following table:

Substance	"Available Chlorine" Content
Cl_2	100%
HOCl	135.6%
NaOCl	95.4%
$CaOCl_2$	56.0%
Bleach (impure $CaOCl_2$)	35.0%
$Ca(OCl)_2$	99.2%
HTH (impure $Ca(OCl)_2$)	70.0%
$NaClO_2$ (sodium chlorite)	158.0%
ClO_2 (chlorine dioxide)	250.0%

The oxidizing power of chlorine dioxide, stated in terms of "available chlorine," is two and a half times that of chlorine itself. This is illustrated on a molecular basis as follows:

$$ClO_2 + 2\tfrac{1}{2}\ H_2 \longrightarrow HCl + 2\ H_2O$$
$$Cl_2 + H_2 \longrightarrow 2\ HCl$$

Chlorine Dioxide for Water Treatment

The development of a practical method for generating chlorine dioxide led to investigations of its use in water treatment for the destruction of tastes and odors (caused by phenolic wastes or algae), and for disinfection.

Bactericidal Action.—Chlorine dioxide, in our experience, is a more effective bactericide than chlorine when tested on distilled water to which E. Coli has been added. When used on polluted water, however, chlorine dioxide, because it is much more reactive than chlorine, destroys phenols, algae and other pollutants at the same time or prior to its attack on bacteria. For this reason the disinfection of polluted waters requires more chlorine dioxide than chlorine. This conclusion, stated by McCarthy[7] was borne out in a series of experiments using the following waters:

a. Merrimac River—Tap water from Lawrence, Mass.—culture of E. Coli added.
b. Merrimac River—Untreated—filtered only.
c. Niagara River—Tap water from Niagara Falls—culture of E. Coli added.
d. Niagara River—Untreated—filtered only.
e. Ohio River—Untreated—filtered only—from Cincinnati.

The results of these experiments to determine the comparative amounts of chlorine and chlorine dioxide required to disinfect these various waters are outlined in the following table:*

Water	Coliform Index of Sample	ClO_2 ppm.** for Complete Disinfection	Cl_2 ppm.** for Complete Disinfection
(a)	1,000,000	2.0	0.50
(b)	100,000	2.4	0.8-1.0
(c)	1,000,000	0.6	0.6
(d)	100,000	1.4	0.8
(e)	100,000	1.2	1.0

A comparison of the demand of these waters, i.e., to produce a test for residual chlorine, is shown as follows:

*Procedures as outlined in "Standard Methods of Water Analysis" were used throughout this work.
**Listed as ppm. available chlorine.

Water	ClO_2 Demand	Cl_2 Demand
(b)	1.99	0.66
(d)	1.01	0.66
(e)	0.89	0.65

The basic chlorine demand of these various waters remains fairly constant, but the chlorine dioxide demand varies with the degree of pollution, inasmuch as the chlorine dioxide reacts more readily with polluting substances than does chlorine. Therefore it will require more chlorine dioxide than chlorine to attain the disinfecting reaction.

Taste and Odor Control—For the improvement of taste and odor, chlorine, as ordinarily applied, has not been found to be entirely satisfactory, especially where phenolic pollution or considerable algae growths occur. The breakpoint method of chlorination, developed for this purpose within the past six years, is not always adequate. Where sharp breakpoints fail to occur, or where sudden fluctuations in pollution tax the chlorinator beyond its capacity, temporary shut-downs, or even new sources of water supply, become necessary.

Such a situation existed in an auxiliary filter plant of the City of Niagara Falls (N. Y.) Water Department. This plant, which supplies 3 to 8 mil. gal. per day, or approximately 10 to 20 per cent of the total water supply, has an "on-shore" intake which becomes so polluted at some times with phenolic compounds and at other times so infected with algae that the ordinary method of treatment has often failed to produce a palatable water. This condition is intensified by the fact that phenolic pollution comes in surges rather than at a constant rate, so that the water varies greatly even from hour to hour.

Treatment Used at Niagara Falls

Experiments undertaken at Niagara Falls to study the possibilities of chlorine dioxide as a solution to this problem have demonstrated that chlorine dioxide destroys such tastes and odors.[8]

Because information on the bactericidal action of chlorine dioxide is still incomplete, it was considered inadvisable to attempt to utilize chlorine dioxide now used for disinfection of the water. The treatment as developed at Niagara Falls therefore combines pre-treatment with chlorine for disinfection and post-treatment with chlorine dioxide to destroy taste and odor.

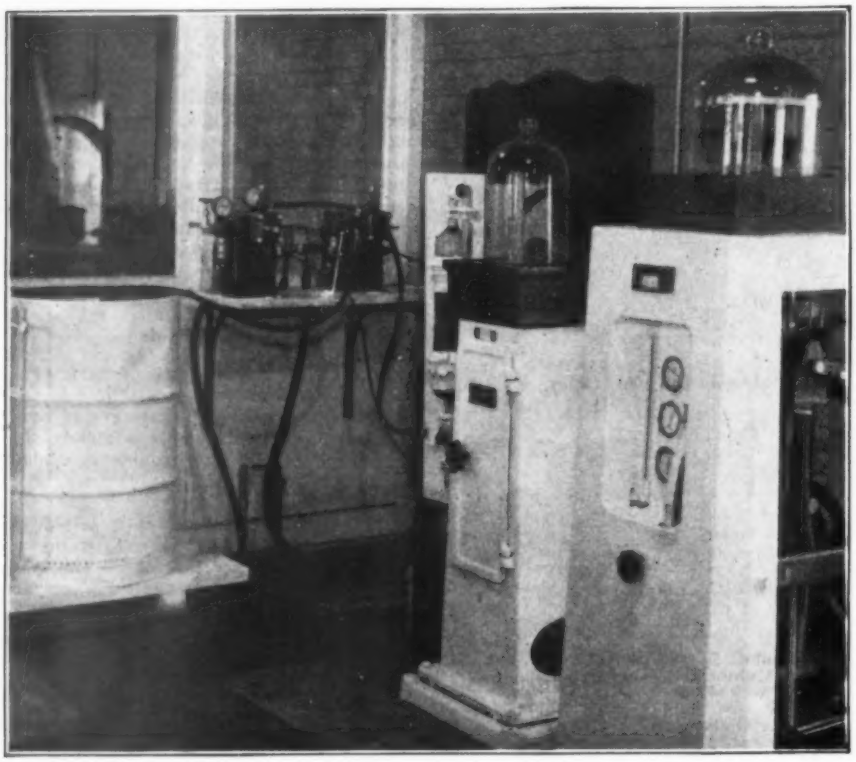
In the pre-treatment, sufficient chlorine is fed to maintain a residual available chlorine of 0.4 to 0.5 ppm. in the settling basin and 0.2 ppm. under the filters. This residual was regulated at first by the addition of carbon. Subsequently it was found that the use of carbon was unnecessary, and the residual is now being maintained simply by regulating the chlorine feed. A dosage of 1.5 ppm. chlorine is ordinarily sufficient for the purpose, but is increased when the chlorine demand of the water increases.

Along with addition of chlorine, alum is added for clarification. Usually, 17 ppm. of alum is sufficient, and the water is held in the settling basin for three hours, after which it is filtered. Following this treatment, chlorine dioxide is introduced at the clear well in the manner described in the following paragraphs.

The sodium chlorite solution, containing 31 grams per liter of available chlorine, is fed by means of a metering pump into the discharge line of a Wallace & Tiernan chlorinator (shown in accompanying photographs), at the rate of 1.65 gallons of solution, or 0.42 pound available chlorine, per hour. The chlorinator is set to deliver 2 lb. of chlorine per mil. gal., equivalent to 0.25 lb. of chlorine per hour, at a pumping rate of 3 mgd. (The accompanying flow diagram shows the pretreatment, coagulation, filtration, and chlorine dioxide treatment.)

To assure complete conversion of chlorite to chlorine dioxide, an excess of chlorine is used. The reaction mixture is passed through a mixing chamber before entering the wall. The chlorine dioxide dosage is maintained at a value of 0.5 to 0.75 ppm. available chlorine.

During the test runs, the concentration of phenol in the river was very high.



Apparatus for Chlorine Dioxide Treatment of Water at Niagara Falls, N. Y. (At the left is the chlorite solution tank; center are the chlorite pumps, mixer and chlorinator for generation of chlorine dioxide applied as a post-treatment; at the extreme right is the chlorinator used for pre-chlorination.)

Breakpoint tests in the laboratory indicated that, with the old method, doses of 15 ppm. of chlorine would have been required in some cases; and, on at least one occasion during the test period, the plant would not have been able to feed enough chlorine to handle the load, and would have been forced to shut down.

The taste and odor producing substances at the time of the initial tests were chiefly phenolic, inasmuch as this is the characteristic difficulty of the Niagara Falls water supply during the winter months. In the warm weather, however, the taste and odor difficulties are mainly the result of algae growths. Chlorine dioxide treatment eliminates both difficulties efficiently and completely.

The entire water supply system of the city of Niagara Falls is now protected by chlorine dioxide treatment, to give year-'round operations without taste and odor difficulties.

Chemical Saving

It has been found, also, that a considerable saving in chemical costs is obtained by the use of the new method. On the basis of operation during one week the comparative costs were:

Old Method:

1080 lbs. chlorine
1800 lbs. carbon

Total cost $157.50
Cost per million gallons.. ..... 8.73

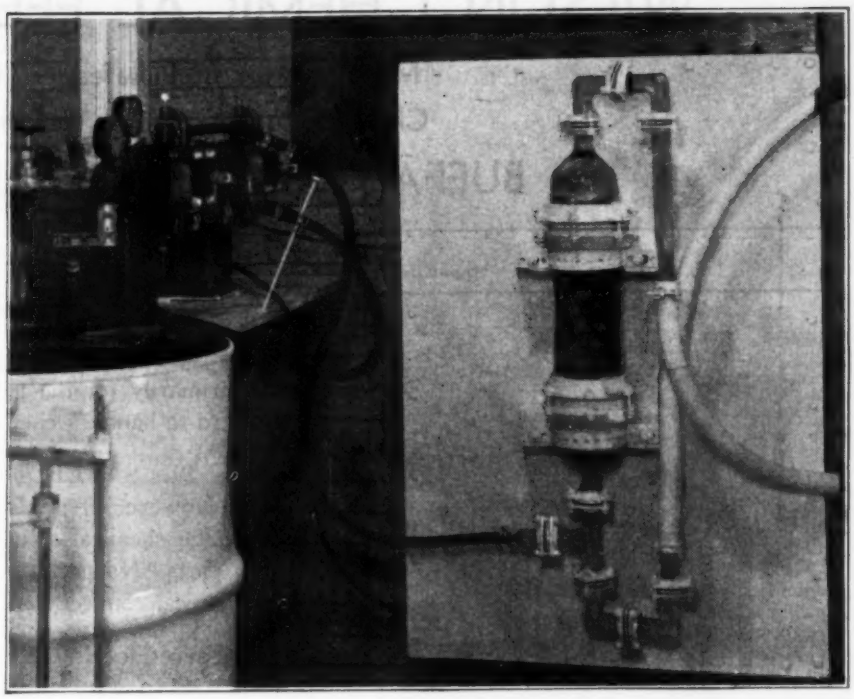
New Method:

163 lbs. chlorine
46.2 lbs. chlorite

Total cost .....$ 43.10
Cost per million gallons..... 2.39

The saving per million gallons over the old method of treatment, therefore, was $6.34, or 72.5 per cent.

In addition to the saving in the cost of materials, plant operations have been simplified by the elimination of careful breakpoint measurements.



Close-Up View of Auxiliary Equipment Required to Generate Chlorine Dioxide (Chlorite solution pumped from solution tanks at the left and chlorine solution fed from chlorinator to the right, react in the glass mixer to form a solution containing chlorine dioxide.)

Summary

1. A new method of taste and odor control in water treatment has been described.

2. The method involves pretreatment of water with chlorine to disinfect it, followed by treatment with chlorine dioxide to destroy tastes and odors due to algae or phenolic wastes.

The new treatment permits continuous operation, reduces the amount of chlorine required, eliminates the use of carbon, and simplifies operation by making breakpoint measurements unnecessary.

4. Chlorine dioxide has also demonstrated bactericidal action, the dose required for disinfection varying with the amount of pollution.

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7. McCarthy, James A., J.N.E. Water Works Ass'n, March, 1944.

TO STOP PIPE SWEATING*

The following formula, directions for application, and specifications for materials required in the application of an insulating protective coating for stopping troublesome sweat formation on pipes, pumps, small tanks, etc., has proved highly satisfactory according to Chas. P. Hoover, Consulting Chemical Engineer and 1st Ass't. Superintendent of Water Works at Columbus, Ohio.

Application Procedure

All surfaces must be absolutely clean and dry before any applications are made. The outside surface is first painted with a thick coat of adhesive (specified herein), after which a thick coat of ground cork is either blown or pressed on by hand. This ground cork must be built up to a uniform thickness on all exposed surfaces. After this application is thoroughly dry, a second thick coat of adhesive is applied, after which the second thick layer of ground cork is either blown or pressed on by hand. The second layer of ground cork must also be built up to a uniform thickness. After the second application is thoroughly dry, it is covered with two coats of an approved paint.

The Adhesive

The adhesive is made up of the following materials:

Ingredients	*Proportions*
Whiting, dry	7¾ lbs.
Interior Varnish	4¼ lbs.
Raw Linseed Oil	¼ lb.
Paint Dryer	¼ lb.

Cork Specifications

In purchasing the cork to be used the following specifications will be found helpful:

The cork shall be equal in quality to 8/14 granulated cork as manufactured by the Armstrong Cork Co., Lancaster, Pa. It shall be ground so that not less than 95% by weight of the particles will pass through a No. 8 U. S. standard sieve and not more than 5% by weight will pass through a No. 14 U. S. standard sieve. The cork shall not weigh more than 8 lbs. per cubic foot. The cork shall contain not more than 1.5% of dirt, dust, or other foreign matter.

It is to be noted that all of the above, with slight changes in a word here and there, will produce a complete specification for materials as well as the method of application should the insulating job be let to contract.

*By Chas. P. Hoover, Principal Ass't Superintendent, Division of Water, Columbus, Ohio.

WILSON CHEMICAL FEEDERS, INC.

Manufacturers of Pulsafeeders for
Chemical Solution Water Treatment

BUFFALO, NEW YORK, U. S. A.

THE WILSON "PULSAFEEDER"

is a positive displacement, pump type chemical solution feeder; designed primarily for the feed and accurate control of both corrosive and "hard-to-handle" chemicals.

Basically PULSAFEEDER is in the family of accurate piston pumps. However, it is also equipped with a diaphragm to actually separate the chemical solution being pumped, from all operating or moving parts. No packing glands are used, and the diaphragm has no mechanical connections.

Low pressure models of PULSAFEEDER handle solutions against pressures up to 200-lbs. per sq. in. High pressure models are good up to 1500-lbs. per sq. in. Sizes are available up to 400-gals. of solution per hour.

CHEMICAL SOLUTION WATER TREATMENT

HYPO-CHLORINATION

The PULSAFEEDER was originally designed for use with either calcium or sodium hypochlorite. A complete treatment system is available for either manual, semi-automatic or fully automatic operation. Feeds all concentrations; supplies up to 500,000 gals. of water per day.

COAGULATION

Accurate control of coagulation chemicals for water or sewage filtration, employing use of aluminum salts, iron salts and the like. Units available in capacities up to 400-gals. per hour.

pH CONTROL

PULSAFEEDER's principal of chemical solution isolation allows for feed of all concentrations of acids and alkalis. Guarantee of not more than ⅛ of 1% feed variation assures accurate pH control.

CALGON FEEDING

Scale prevention, iron control, corrosion control all handled expertly by PULSAFEEDER. Hundreds of units are in use in water supplies of all types and sizes.

ODOR, TASTE AND COLOR CONTROL

Problems involving odor, taste and color control are all within the scope of WILSON PULSAFEEDERS. Write us for recommendations.

OTHER USES

PULSAFEEDERS are also adapted to many processing problems, food equipment sterilization, boiler chemical feed, automatic blending operations, and other accurate proportioning problems.

Manual and Fully Automatic PULSAFEEDERS

The various PULSAFEEDERS use either electric motor, gasoline engine, water or air motor drives, and are controlled by water meters of all types if flow-proportional feed is desired. The types below represent a complete line of chemical water treatment apparatus.

MANUAL

Type DES—
Electric motor driven simplex model, for feed of a single chemical solution.

Type DED—
Electric motor driven duplex model, for feed of two solutions. Used widely for chloramines.

Type DET—
Electric motor driven triplex. Generally used for hypochlorite, soda ash and alum. For feed of three solutions.

Type DEQ—
Electric motor driven quadruplex. For feed of four solutions simultaneously, each feed independently adjustable while in operation.

Type DEG—
Emergency portable model for water sterilization. Feeds against 200-lbs. per sq. in. Capacity 300-lbs. chlorine per 24 hours.

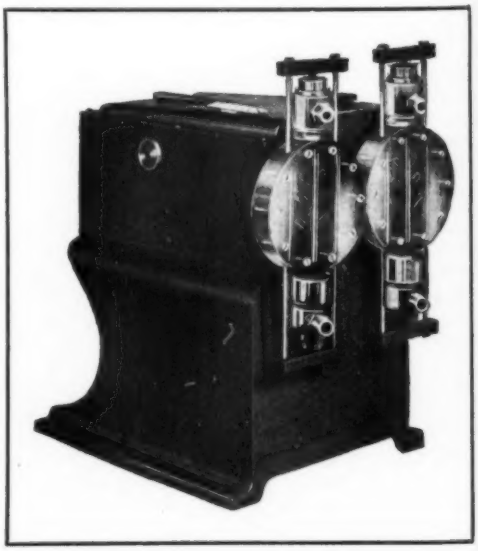
AUTOMATIC

Type MC-DES—
Electric motor drive, meter controlled. Applicable to all liquid meters. Single and multifeeders.

Type MC-DS—
Water or air motor drive, meter controlled. Applicable to all meters. Single and multifeeders.

Type MC-WD—
Water or air motor powered, meter controlled, marine type. For installations aboard ship.

Type SP—
Flow-proportional, pressure differential feeder for operation with orifices, flow nozzles or venturi. Operates on 1" water differential and up.



IMPROVED RESIDUAL CHLORINE TEST*

The Ortho-tolidine: Arsenite (OTA) Method for Testing Water for True, False and Chloramine Residuals

By F. W. GILCREAS

Division of Laboratories and Research, New York State Department of Health, Albany, N. Y.

THE reaction of free available chlorine with ortho-tolidine is practically an instantaneous one, requiring less than fifteen seconds for development of the color; thus the appearance of an immediate or flash color may be used as a measure of free chlorine present.

This flash color may be quantitatively estimated if a weak reducing agent such as sodium arsenite is added to the sample approximately fifteen seconds after the addition of the ortho-tolidine. (Step A) The sodium arsenite neutralizes all combined chlorine before it can react with the ortho-tolidine reagent. The flash color is not affected by the sodium arsenite reagent, but remains unchanged and may be read by comparison with permanent standards at any time within five minutes.[1]

When sodium arsenite is added first to the sample, (step B) all chlorine, both free and combined, is neutralized. Ortho-tolidine reagent added subsequently reacts with manganese and other interfering substances present, which are not affected by the sodium arsenite reagent, but which produce a color with ortho-tolidine similar to that indicating chlorine. This color may likewise be measured by comparison with chlorine standards.

Using readings obtained from these two procedures (steps A and B) and that of the standard ortho-tolidine test, it is possible to measure free available chlorine, combined chlorine, and ortho-tolidine color caused by interfering substances. The portion of sample to which ortho-tolidine reagent is added first, followed by the arsenite reagent, (step A) yields a color representing both free available chlorine and any interfering substances present. In the portion to which arsenite is added first, followed by ortho-tolidine reagent, (step B) the color produced represents interfering substances only. Thus, free available chlorine may be determined by subtracting the second value from the first. The false residual chlorine value is the second reading, (obtained in step B). If the reading of the first step is subtracted from that of the standard ortho-tolidine test for total chlorine, the residual chlorine value corresponding to combined chlorine or chloramine is obtained.

The determination of the free available chlorine, the combined chlorine, and the interfering substances may be facilitated by use of a technic employing the double-bottle method. Under routine operating conditions, however, it may be possible to dispense with this procedure and use only those determinations that are of most help in the control of chlorination in each particular plant. In any case the OTA test does not outmode present standard equipment for determining residual chlorine.

Reagents[2]

Ortho-tolidine reagent—method 1. Dissolve 1.35 grams ortho-tolidine dihydrochloride in 500 ml. distilled water. Add this solution, with constant stirring, to 500 ml. dilute hydrochloric acid made by mixing 350 ml. distilled water and 150 ml. concentrated hydrochloric acid (sp. gr. 1.18-1.19).

Ortho-tolidine reagent—method 2. Grind 1 gram ortho-tolidine in a mortar with 5 ml. dilute hydrochloric acid made by adding 150 ml. concentrated hydrochloric acid (sp. gr. 1.18-1.19) to 350 ml. distilled water. Add 150-200 ml. of distilled water. The ortho-tolidine goes into solution immediately. Transfer the solution to a 1-liter graduate and add the balance (495 ml.) of the dilute acid and make up to 1 liter with distilled water.

Storage of ortho-tolidine reagent. Dispense this reagent in two-ounce French square brown glass bottles. Store in dark when not in use, and avoid exposure to low temperatures. The solution should be clear and colorless; discard it if it becomes either colored or turbid. Certain types of rubber stoppers are attacked by the strong acid and yield reducing substances that cause the reagent to deteriorate.

At temperatures below 0° C. the ortho-tolidine will precipitate from solution and will not redissolve readily. Any reagent containing a precipitate should not be used.

Sodium arsenite reagent. Dissolve 0.5 grams of sodium arsenite in distilled water and make up to 100 ml. Store in any sized bottle but use in a properly labeled 2-oz. French square reagent bottle with a screw cap medicine dropper.

*This article is cited from material prepared by the author for use, in New York State, in connection with the OTA Test.

Permanent Chlorine Standards[2]

0.5 *M phosphate buffer solution.* Allow a sufficient quantity of disodium hydrogen ortho-phosphate dodecahydrate ($Na_2HPO_4 \cdot 12H_2O$) to dry over a saturated solution of potassium carbonate ($K_2CO_3 \cdot 2H_2O$) until the weight remains constant for one week, and weigh as $Na_2HPO_4 \cdot 2H_2O$. If disodium hydrogen ortho-phosphate anhydrate (Na_2HPO_4) is used, dry at 110° C. and cool in a desiccator.

Dissolve 28.66 grams disodium hydrogen ortho-phosphate dihydrate ($Na_2HPO_4 2H_2O$) (or 22.86 grams Na_2HPO_4) and 46.14 grams potassium dihydrogen ortho-phosphate anhydrate (KH_2PO_4) in 1 liter of distilled water. Let stand for at least several days before using, to allow time for formation of any precipitate, which must be filtered out prior to use.

0.1 *M phosphate buffer solution* (pH 6.45). Filter solution as prepared above and dilute 200 ml. to 1 liter with distilled water.

Strong chromate-dichromate solution. Dissolve 1.55 grams potassium dichromate ($K_2Cr_2O_7$) and 4.65 grams potassium chromate (K_2CrO_4) in 0.1 M phosphate buffer and dilute to 1 liter with the 0.1 M phosphate buffer. This solution represents 10.0 ppm. chlorine when viewed through a 240-300 mm. depth.

Dilute chromate-dichromate solution. Dissolve 0.155 grams potassium dichromate ($K_2Cr_2O_7$) and 0.465 grams potassium chromate (K_2CrO_4) in 0.1 M phosphate buffer and dilute to 1 liter with the O.1 M phosphate buffer. This solution may also be prepared by diluting 100 ml. strong chromate-dichromate solution to 1 liter with 0.1 M phosphate buffer. The solution represents 1 ppm. chlorine.

Preparation of standards. Measure the volumes of dilute chromate-dichromate solution given in Table I into clean two-ounce French square bottles of clear glass and dilute to exactly 50 ml. with the 0.1 M phosphate buffer solution.

TABLE I

Chlorine Standards—Modified Scott Formula 0.05-1.0 ppm.

Chlorine Standards ppm.	Dilute chromate-dichromate solution ml.	Chlorine Standards ppm.	Dilute chromate-dichromate solution ml.
0.05	2.5	0.40	20.0
0.10	5.0	0.50	25.0
0.15	7.5	0.60	30.0
0.20	10.0	0.70	35.0
0.25	12.5	0.80	40.0
0.30	15.0	1.00	50.0

The standards should be protected from contamination by dust by keeping the bottle closures tightly screwed down or by sealing the closure with collodion or paraffin. The standards must be stored in the dark and renewed if any trace of turbidity appears in them.

Apparatus

1. Two-ounce French square bottles.
2. Medicine dropper caps to fit French square reagent bottles.
3. Commercial test kits may be used.

Procedure for Ortho-tolidine-Arsenite (OTA) Test

1. Select three two-ounce French square bottles; mark one A, one B, and one OT.
2. Add 50 ml. of a sample of chlorinated water to each of the three bottles.
3. Unscrew, and fill droppers of both reagent bottles, one with ortho-tolidine, the other with arsenite.
4. Hold samples for the required period of contact, usually ten minutes, unless a period longer than that has elapsed between the application of the chlorine and collection of the sample.

   All operations noted in paragraph 5 should be carried out as rapidly as possible. For each bottle, the addition of reagents and mixing should be completed within ten to fifteen seconds.
5. Add a dropperful of ortho-tolidine to bottle marked OT. Mix by one quick shake.
   Add a dropperful of ortho-tolidine to bottle marked A; mix.
   Add a dropperful of arsenite; mix.

Add a dropperful of arsenite to bottle marked B; mix. Add a dropperful of ortho-tolidine; mix.

6. If the sample is cold, warm portion OT to 68° F. in a bath of warm water or by holding in the hand. Portions A and B do not require warming since the rate of color development is independent of the temperature.
7. Free available residual chlorine. Three minutes after addition of the ortho-tolidine, read portions A and B in comparison with color standards. Subtract the reading for B from that for A; the difference is the free available chlorine present.
8. False residual. Read portion B alone in comparison with color standards four minutes after addition of ortho-tolidine. If sample is colored or turbid use an untreated sample blank as in the standard ortho-tolidine test. This reading is due to interfering agents only.
9. Standard OT test. Read OT portion at four and one-half minutes in the usual manner.
10. Combined chlorine. Five minutes after addition of ortho-tolidine, read portions OT and A in comparison with color standards. Subtract the reading for A from that for OT; the difference is the combined chlorine (chloramine). If this reading exceeds 0.05 ppm., read again at fifteen minutes to allow for the slower development of color due to combined chlorine. Read portion OT again just prior to the fifteen-minute combined chlorine reading.
11. The following table gives the times and relations between the various readings.

	Read at*
A minus B	3 minutes = free chlorine
B	4 minutes = false residual
OT	4½ & 14½ minutes = total chlorine & false residual
OT minus A	5 & 15 minutes = combined chlorine

Procedure for Ortho-tolidine-Arsenite Test Using Commercial Test Kits

Four cells are necessary to perform the complete test. If only two are available, the test may be divided into two parts, the A and B portions and then the OT and A portions repeated. A large sample of water should be collected and both parts of the test carried out on the same sample. The procedure and the amounts of reagents are the same as for the test using 50-ml. portions in French square bottles. Because of the higher acid concentration present when the reagent is added to 15-ml. portions, it is not necessary to wait fifteen minutes for full color development due to combined chlorine; five minutes is sufficient.

*The combined chlorine reading must be made exactly at five minutes and at fifteen minutes because of the changing color. For the same reason it is essential to read B just after A minus B and to read OT just before OT minus A. The timing for the other readings is suggested for convenience.

Limitations

Certain limitations in the technic are mentioned by Hallinan in his original publication of the ortho-tolidine-arsenite test.[1] In the test for chloramine, owing possibly to the incomplete reaction between arsenite and chloramine, the results may be 3.5 per cent low, an appreciable but not significant error. Products of the reaction of chlorine with organic matter, particularly amines, may also be included in the chloramine reading; thus, differentiation of chloramine from other forms of combined chlorine cannot be made.

The use of two reagents and the speed required in their addition have not been found to complicate the technic. In general practice, the technic has proven effective in the detection of interfering substances in an amount not greater than the equivalent of 1 ppm. of chlorine. As with all colorimetric methods, the precision of the test is governed by the limitations of color comparison, particularly in ranges of high color intensity. The test is effective in differentiating free available chlorine from that combined with ammonia or other forms of nitrogenous organic matter.

Results of Application of the OTA Test

The test has been used routinely for a period of one month by the operators of 23 water supplies in New York State.[3] Of 659 days represented by the readings of these 23 supplies, a false residual was found on 102 days; and on 84 days the chloramine residual was 0.3 ppm. or less, with no active chlorine present. Three of the cooperating water supply operators reported definite false residual values repeatedly; and from these supplies samples of the water examined subsequently were found to contain significant amounts of manganese.

The results of this study indicated that the OTA test provides a quantitative estimation of the type of residual maintained in any given water, whether free available chlorine or the less bactericidal combined chlorine, and that it also provides a precise reading for the determination of substances which interfere with the ordinary ortho-tolidine technic. Thus, it has a definite application in the control of chlorination of water, particularly for those supplies in which such interfering substances may be continuously or intermittently present.

References

1. Hallinan, F. J. Tests for active residual chlorine and chloramine in water. *Jour. Amer. Water Works Assoc.*, **36**, 296-302 (1944).
2. Committee on Control of Chlorination. American Water Works Ass'n Report, 1943. *Jour. Amer. Water Works Assoc.*, **35**, 1315-1328 (1943).
3. Gilcreas, F. W., and Hallinan, F. J. The practical use of the ortho-tolidine-arsenite test for residual chlorine. *Jour. Amer. Water Works Assoc.*, **36**, 1343-1348 (1944).

CONCRETE

Quantities of Materials for One Cu. Yd. Rammed Concrete Based on Barrel of 3.8 Cu. Ft.

	Using ¾-in. Gravel and Under, Sand Screened Out			Using 1-in Stone and Under, Dust Screened Out		
Proportions	Cement Barrels	Sand Cu. Yds.	Gravel Cu. Yds.	Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.
1:1½:3	1.71	0.39	0.78	1.85	0.42	0.84
1:2 :4	1.34	0.41	0.81	1.46	0.44	0.89
1:2 :5	1.17	0.36	0.89	1.27	0.39	0.97
1:2½:5	1.10	0.42	0.83	1.19	0.46	0.91
1:3 :5	1.03	0.47	0.78	1.11	0.51	0.85
1:3 :6	0.92	0.42	0.84	1.01	0.46	0.92
1:3½:6	0.88	0.46	0.80	0.95	0.50	0.87
1:3 :7	0.84	0.38	0.89	0.91	0.42	0.97
1:3½:7	0.85	0.43	0.85	0.87	0.47	0.93
1:4 :7	0.77	0.47	0.81	0.83	0.51	0.89
1:4 :8	0.71	0.43	0.86	0.77	0.47	0.93

	Using 2½-in. Stone, Most Small Stone Screened Out			Using 2½-in. Stone and Under, Dust Screened Out		
Proportions	Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.	Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.
1:1½:3	1.96	0.45	0.89	1.90	0.43	0.87
1:2 :4	1.53	0.47	0.93	1.48	0.45	0.90
1:2 :5	1.33	0.39	1.03	1.29	0.39	0.98
1:2½:5	1.26	0.48	0.95	1.21	0.46	0.91
1:3 :5	1.17	0.54	0.89	1.14	0.52	0.87
1:3 :6	1.06	0.48	0.97	1.02	0.47	0.93
1:3½:6	1.00	0.53	0.92	0.97	0.51	0.89
1:3 :7	0.94	0.42	1.05	0.92	0.42	0.98
1:3½:7	0.91	0.49	0.98	0.89	0.47	0.95
1:4 :7	0.87	0.53	0.93	0.84	0.51	0.90
1:4 :8	0.81	0.49	0.98	0.78	0.48	0.95

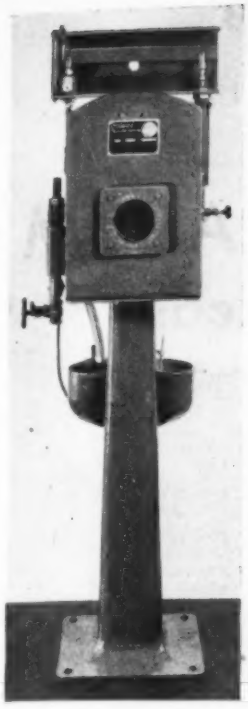
Figure about 1¼ cu. yds. of pit run gravel to make one cubic yard of rammed concrete.

Variations in fineness of the sand and the compacting quality of the concrete may affect the above quantities 5 to 10% in either direction.

Weights of Cement, Crushed Stone, Gravel and Sand

Material	Weight per Cu. Yd.	Material	Weight per Cu. Yd.
Bank sand	2,500	Screenings	2,500
Torpedo sand	3,000	Gravel	3,000
Crushed stone	2,500	Roofing Gravel	3,000

Portland cement weighs 94 lbs. per bag, or 376 lbs. per bbl. One bag is equivalent to 1 cu. ft.



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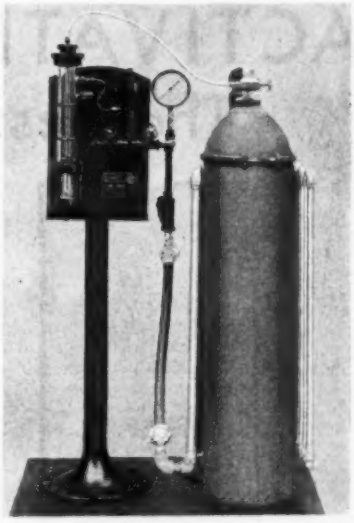
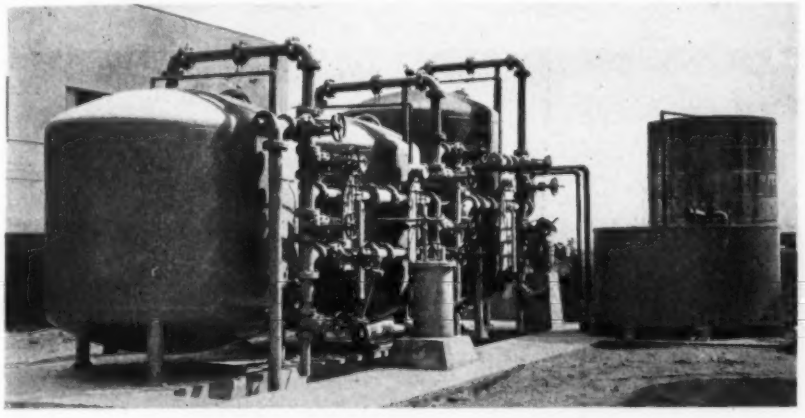
Left — Type MI C H E M C O CHLORINATOR, equipped for stop-start duty.



Right—A CHEMCO M-5 Vacuum type, Solution fed Chlorinator.



CHEMCO ZEOLITE WATER SOFTENERS

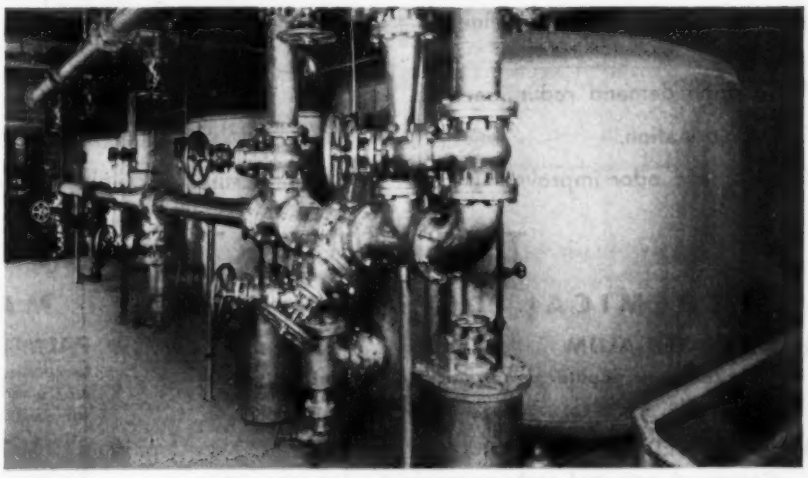
using either natural green sand, white synthetic zeolites, or resinous type minerals—are available in all capacities from the smallest private home to the large installations for industrial, municipal and institutional applications. Many CHEMCO units have been installed in Government cantonments and hospitals, industrial plants and municipal waterworks.

The illustration on the left shows a CHEMCO 2-unit, softener and filter installation at new City of Glendale Municipal Power Plant.

SAND PRESSURE AND GRAVITY SAND CHEMCO FILTERS

CHEMCO pressure filter installations, are especially engineered for water supply and swimming pool service, therefore offer many simplifications over conventional types of commercial filters. They are engineered, fabricated, and installed for each filtering problem and filtering capacity desired. The many construction and operating advantages assure utmost efficiency and long life. Wood tank gravity and filters are also available.

Of special importance is the fact that CHEMCO filter plants are designed for the necessary high "back-wash" rates as well as the lower filtering rates. This is essential for prevention of plugging up the filter bed and resultant necessities of a new sand refill every few years. The illustration on the right shows one of four CHEMCO 4-unit 96″ I.D. Installations for Count of Los Angeles.



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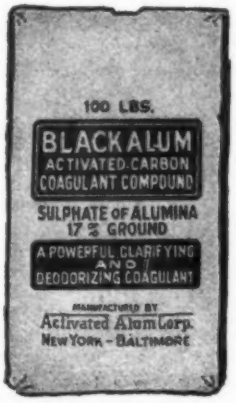
By the use of Blackalum, troubles resulting from red water are successfully eliminated.

Due to its powerful deodorizing and decolorizing properties waterworks engineers claim that Blackalum is exceptionally economical.



10 TECHNICAL ADVANTAGES

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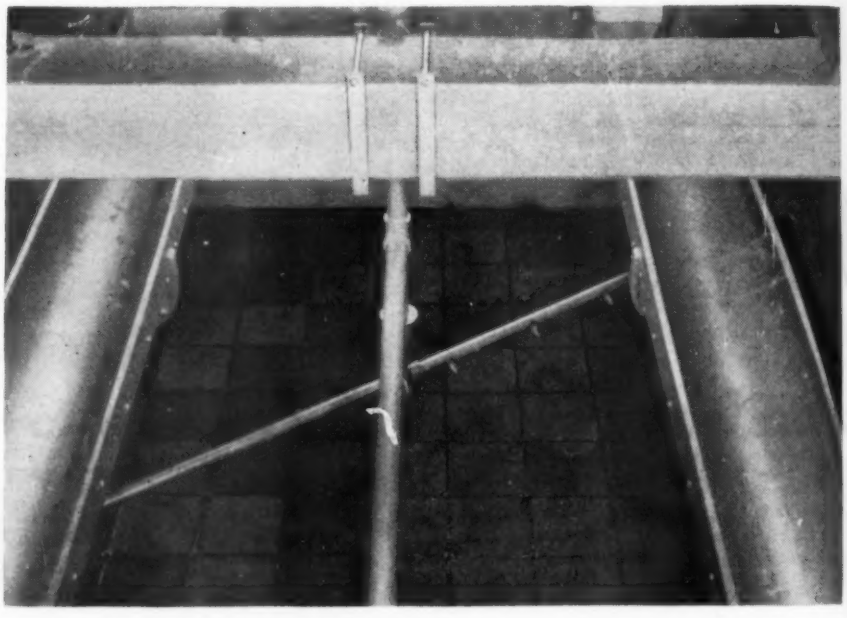

Palmer Filter Bed Agitators installed between concrete wash water troughs.

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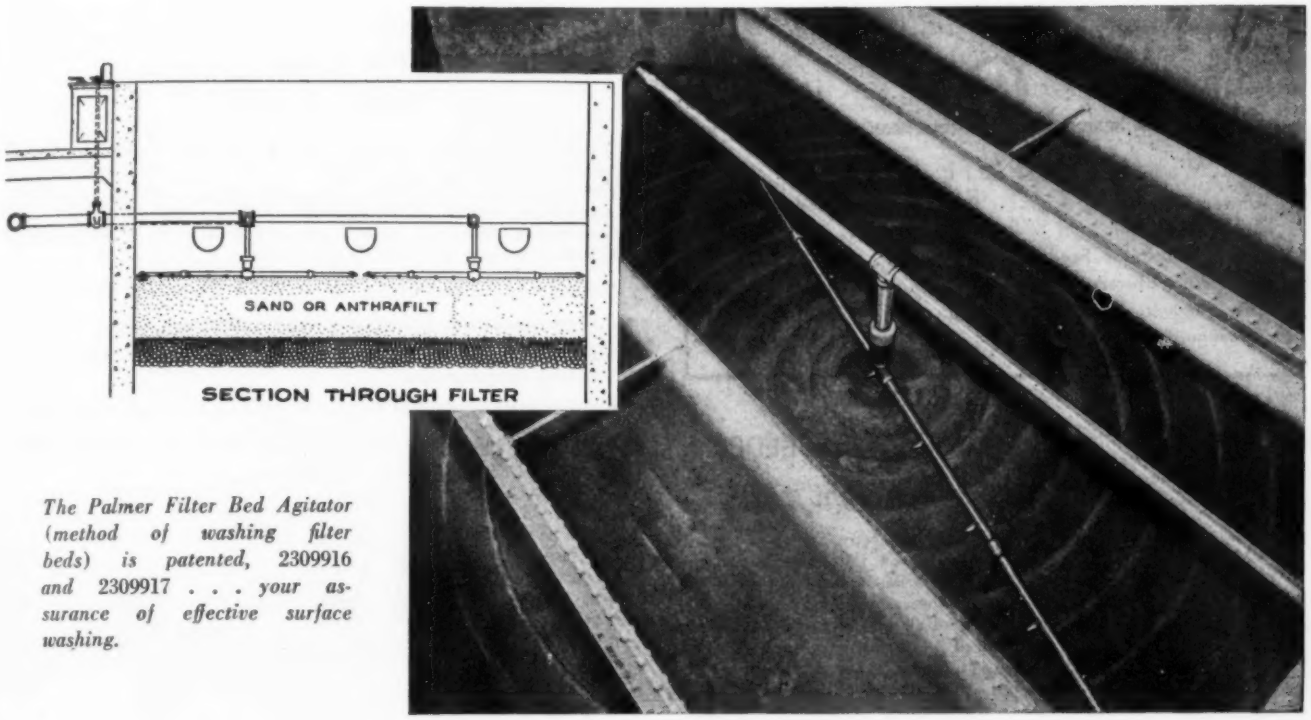

The Palmer Filter Bed Agitator (method of washing filter beds) is patented, 2309916 and 2309917 . . . your assurance of effective surface washing.

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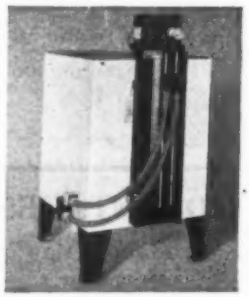
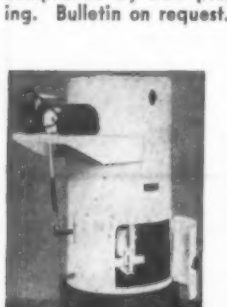
The most accurate type chemical feeder made. Indicates on the scale beam the weight of material in the hopper at all times. Feeds lump, granular or powdered materials at 100 different rates by increments of 1% of the maximum rate of feed, and records every pound of material fed. No calibration is required. The rate of feed is automatically controlled by the loss in weight in the hopper of material. The No. 1 Feeder shown at left feeds up to 2,000 lbs. per hour. Bulletin on request.

PRECISION FEEDER



Not an orifice feeder but a true Volumetric feeder, accurate within 1% for feeding solutions of Calgon, hypochlorite, copper sulphate, ammonium sulphate, etc., by gravity. Feeding range 100 to 1, from 1/25 to 200 gals. per hour, with standard tank sizes 25 to 200 gallons. Where electricity is not available, 8-day spring motors are used; meter-paced control is easily accomplished by flow proportional feeding. Bulletin on request.



UNIVERSAL FEEDER

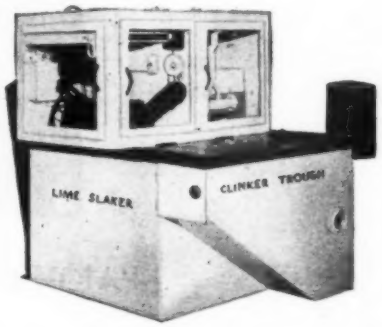
A rugged, dependable Volumetric feeder with oscillating throat at base of hopper. Easy micrometer screw adjustment gives a practical range of 40 to 1. Three sizes provide a feeding rate of 1 to 6,000 lbs. per hour. The feeder will successfully handle lime containing both lumps and fine powder; strings and trash will pass on through without clogging. Accuracy averages 3% although crushed lime may vary somewhat in weight per unit of volume. Send for Bulletin.

OMEGA LIME FEEDERS AND SLAKERS

Omega Continuous Lime Slakers are the product of years of specialization in the design and construction of equipment for Municipal Water and Sewage Plants. The majority of Omega Lime Slaker installations employ either the Belt Type or Loss-In-Weight Type Gravimetric Feeders. Slakers are available with capacities from 175 lbs. per hour to 10,000 lbs. per hour.

Outstanding features of the Omega Lime Slaker include:

- High speed mixing to promote rapid, thorough slaking.
- Efficient insulation and thermostatic heat control to maintain high slaking temperatures.
- Vapor removal devices to protect feeders from hot, moist vapors.
- Heat exchanger coils to preheat cold water for increased slaking efficiency.



OMEGA BELT TYPE GRAVIMETRIC FEEDER AND 500 LB./HR. OMEGA SLAKER

A feeder of extreme accuracy, weighing material continuously on a short conveyor belt carried on accurate sensitive scales. Can be set by a single dial to feed within 2% of the desired rate, and any departure from weight per unit of volume is automatically compensated. Alarms prevent over or under feeding; totalizer and recorder keep complete records of material fed. Automatic devices for feeding in proportion to variable flow are available. Bulletin on request.

OMEGA VOLUMETRIC FEEDER AND 250 LB./HR. OMEGA SLAKER

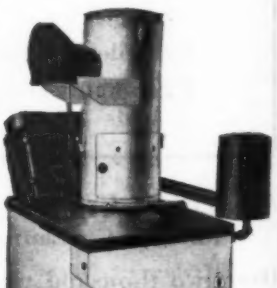


Illustration at right shows the Universal feeder described at left, mounted over a 250 lb./hr. Omega Lime Slaker. These "Old Reliables" are frequently used in combination with Omega Lime Slakers where quantities are small and gravimetric accuracy is not required.

LIME AND LIME SLAKING

By H. E. LORDLEY
Plant Manager, Department of Public Utilities
Richmond, Va.

LIME is one of the oldest chemicals known to civilization, yet today the efficient utilization of this important chemical is impeded by lack of complete information concerning its physical and chemical properties. Since lime is used in such large quantities for softening and corrosion control in the water works field, it is amazing that so little information is to be found in water works literature on the subject of lime and lime slaking.

There Is Lime and Lime

Limestone, which is the source of the calcium oxide, will vary in physical and chemical properties in different parts of the country. Some limestone is high in magnesium which is objectionable for use in water purification plants, yet suitable for other chemical processes. Other sources are high in iron and silica, so it is well to study an analysis of the raw stone before buying lime for the water plant. At the lime plant, in the first step of processing the rock for calcining, a superoir finished product results if mud, sand, and other impurities are removed before burning. In the actual calcining step, the manufacturer can control both the physical and chemical properties of the lime, either by the type of kiln or the method of firing. Therefore, we get much lime that is either under-burned or over-burned by lack of control of the process at the kiln.

Take, for example, the old style vertical kiln using coal as a source of heat without modern control equipment, we find that the lime thus burned will slake very slowly. On the other hand, the modern controlled rotary kiln produces lime that will slake so rapidly that it actually explodes in the slaker. The author recalls an amusing incident at the Richmond Filter plant on changing from a vertical kiln to a rotary kiln lime. The operator frantically called to report that the lime slaker was out of order and making a terrible rumble in the slaking chamber. On investigation, the new rotary kiln lime was producing miniature explositions that sounded like a loose agitator blade. Also common to the old style vertical kiln is the large percentage of core as compared to practically core-free lime from the rotary kiln. So we see that all lime is not the same from every lime plant and the water works executive must choose the source of lime carefully if highest efficiency is to result.

As to Lime Properties

After the lime leaves the kiln it must be graded as to size. Quicklime can be furnished in sizes varying from a fine pulverized product, which will pass a 200 mesh screen, to a pebble lime of two inch size. In determining the proper size to use in the plant, the operator must remember that the pulverized lime offers both a dust problem and a feeding problem due to arching in the hopper. Dust can be controlled by proper ventilating system, but archhing is just a universal worry. Arching can be partly corrected by design of light weight hoppers having a bottom slope of not less than 60° from the horizontal. "Syntron" vibrators on the side of the hopper will further reduce arching, but the best answer is the use of pebble lime of size from ¼ inch to ¾ inch, provided suitable feeding and slaking equipment is available. Dust is reduced, arching in hopper is eliminated, and air-slaking of lime in storage is not as rapid with pebble lime as with the pulverized lime. Another physical property of interest is the color of the lime; white, gray, black, blue, etc. All are high in calcium oxide, and color is not a criterion of a good lime. The chemical properties and specifications are easy to determine in the laboratory. The lime should contain not less tran 90 per cent CaO, have a low magnesia, silica, and iron content, and be free of arsenic.

In many plants today, calcium hydroxide (hydrated lime) is preferred to calcium oxide, due largely to lack of information and equipment for slaking the oxide. The lime manufacturer is anxious to dispose of calcium hydroxide, since all fines from calcium oxide are converted into calcium hydroxide at the lime plant. The water works executive must remember that he pays for slaking process plus freight on water in hauling hydrated lime in preference to burned lime.

Economic Considerations

TABLE I

	Typical Calcium Oxide Lime	Typical Calcium Hydroxide Lime
Insoluble Residue	1.57	.37
R_2O_3	.48	.52
Loss on Ignition	1.34	2.19
Magnesium oxide	1.26	.50
Calcium oxide	95.33	92.00*
CaO Equivalents	96.59	70.00
Cost Price Del./Ton	$11.00	$10.00
Cost Price per ton CaO	$11.38	$14.28

*Calcium Hydroxide—$Ca(OH)_2$ or $CaO + H_2O$.

In Table No. 1, a typical analysis and price of calcium hydroxide as compared to calcium oxide shows the economic status of the two types of lime. In buying a typical pebble calcium oxide in place of calcium hydroxide, a net saving of $2.90 per ton of CaO equivalents is realized, plus higher operating efficiency. In actual plant operation the saving will be greater, since the theoretical ratio of one part CaO to 1.32 parts $Ca(OH)_2$ approaches a practical operating ratio of 1 part CaO to 1.5 parts $Ca(OH)_2$.

Another way to save money in buying quicklime is in the size of the lime. A pulverized calcium oxide (passing 200 mesh) is more costly than a standard pebble or cracked lime. The manufacturer must charge for the expensive process of pulverizing and will raise the price of calcium oxide from $11.00/ton to approximately $13.00/ton for the pulverized product. Also for large plants, the lime shipped in 15 ton cars costs more than in 25 ton cars, due to the freight rates.

With the money that can be saved by shifting from calcium hydroxide to pebble calcium oxide, an excellent feeder and slaker can be purchased and the lime treatment will become a controlled process rather than the usual "hit or miss" process. The operator should investigate and experiment with different types of lime to find the one best suited to his own plant and local conditions.

Lime Slaking Equipment and Its Operation

The operation of the slaker is not easy. Like a man learning to ride a bicycle, the problem looks simple yet requires initial research and a few hard knocks before the art is mastered.

First, and most essential, is an efficient dry-feeder. In the Richmond Filter Plant, an Omega lime feeder delivers the lime to the slaking vat at an astoundingly accurate rate. The feeder is a gravimetric batch type having a maximum capacity of 175 pound/hour and a minimum capacity of 1.75-pound/hour. The feeder has a 1,000 pound capacity, and properly designed hopper equipped with an agitator and mounted on a sensitive beam scale. The adjusting mechanism for changing the rate of feed is located in a compact unit with an alarm to indicate any trouble in feeding, such as an empty hopper or failure of material to leave the hopper. The lime feed is controlled by the vibrating plate at the bottom of the hopper. The pebble lime of size not exceeding ¾ inch size falls off the vibrating plate directly into a compact Omega Slaker located on the same floor with the feeder in a floor space of only 54 inch by 84 inch for both feeder and slaker. The unit is equipped with a water operated vapor removal system to collect dust and steam from the slaker. The water from this unit is not wasted, but is used as make-up water for the slaker or in conveying the lime to the

point of application. The slaker has a minimum retention period of 30 minutes at the maximum rate of feed and is agitated with a motor driven impeller so adjusted to give proper circulation in the chamber.

Temperature Control Important

The optimum temperature for slaking will vary both with the type of lime and the retention period in the slaker. The most efficient slaker temperature range is between 150° F. and 180° F.; above 180° F. the steam and vapor will overload the vapor removal equipment and cause corrosion of the slaker and feeder. In the Richmond plant, the optimum temperature is 160° F. using a pebble lime having a 96 per cent CaO content. In order to maintain this temperature in the shaker, with our incoming water varying between 33° F. and 85° F., an electric water heater of three No. M-240, 4,000 watt Chronolox immersion heaters was purchased for the job. The heaters are equipped with three-way switches for seasonal control and thermostats on each unit to supply makeup water at a uniform temperature regardless of the temperature of the incoming water. The heat of hydration of calcium oxide is 273 calories per gram. However, in slaking small quantities of lime some of this heat is lost and must be supplemented by heat from the make-up water.

Proper Water Ratio

In slaking lime, too little water gives a heavy slurry that is too thick to be agitated properly by the impeller, yet an excess of water increases the expense of heating make-up water and will dilute the lime so that maximum retention time in the slaker is materially reduced. Different brands of lime require variable quantities of water, but a slurry of the proper viscosity is usually obtained by a ratio range of 1 pound lime to 3 pounds water to a ratio of 1:4½. After a series of experiments at the Richmond plant, the ratio of 1:4 was adopted and gives excellent operating results.

To control the ratio, a standard water meter is connected in the supply line to the heater. The meter was geared so that the lowest dial actually reads 3 times the amount of water passing through the meter. For example, one cubic foot of water passing through the meter indicated three cubic feet on the dial. This method was devised to afford the operator a chance to check the water flow at low rates much more readily than with the regular meter dial. After checking the flow, the operator refers to a chart (see Table 2) showing the meter reading corresponding to each rate of lime feed for a ratio of 1:4, adjustment being made by the needle control valve if necessary. Example: Feed 50 lbs./hr. of lime. Requires for ratio 1:4, 50 × 4 or 200 lbs./hr. of water equals

$$\frac{200}{62.4} = 3.2 \text{ cu. ft. per hour of water.}$$

On special dial, this reads 3.2 × 3 or 9.6. On the chart opposite the rate of 50 lbs./hr. is the value 9.6 which should be the reading of the meter for one hour. The operator adjusts the valve to get this reading.

TABLE II

Water Meter Reading vs. Dial Setting for Optimum Ratio one lime to four water.

Pounds/hr. Lime	Dial Setting	Meter Reading (Cu. ft.*)
1.75	1	.3
8.75	5	1.6
17.50	10	3.4
26.25	15	5.0
35.00	20	6.7
43.75	25	8.4
52.50	30	10.0
61.25	35	11.7
70.00	40	13.5
78.75	45	15.1
87.50	50	16.7
96.25	55	18.4

*Special Meter Dial. Indicates three times actual flow.

The lime after slaking is diluted with water from the vapor removal unit and flows over a weir into the outlet line. Some lime has considerable core so that the machine is designed for core removal, without stopping the slaker operation. The core is removed to a chamber to be washed to recover any calcium hydroxide on the surface and is then dumped into a trash can under the slaker. Tests are being run on the amount of unslaked lime in the sample collected at the effluent of the slaker but are not complete enough at present to report in this paper.

Piping Lime Suspensions

No other problem seems more perplexing than that of transporting the lime to the point of application 300 feet or 400 feet from the slaker. If duplicate lines are available, one line can be cleaned with a chlorine solution while the other line is in service. However, caution must be observed to prevent the chlorine from actually attacking the iron pipe. Recently suggested is the use of "Calgon" to keep the lines free of incrustants but so far little work has been reported on this method. Many plants use rubber hose and clean the line by beating or shaking the hose. The author has found that the open trough is the simplest method of delivering the lime, provided the necessary fall between the machine and point of application can be obtained.

pH Control Simplified

So accurate is the control of pH with the new Omega slaker that in the Richmond plant we can hold a constant pH of 8.7 in our finished water. It is important to note in Table No. 3 that prior to the installation of the slaker, we had trouble in our distribution system with a decided drop in pH. Now with the present slaker we have only a slight drop and a corresponding decrease of iron in the dead-ends. We can only explain this by the fact that the controlled slaking is productive of a more highly peptized lime suspension—more nearly a colloidal suspension.

TABLE III

Station No. 34*
Location—Broad Rock Road

	Before Slaker Installation 1938	After Slaker Installation 1940
Res. Cl_2	.00	.00
Turb.	6.0	.80
Color	40	10
Alk. (M.)	23	36
Alk. (Phen.)	0	4.5
CO_2	0	0
pH	8.1	8.6
Fe_2O_3	4.0	.40

*This station is located near a dead-end.

It is hoped that water works men will study lime treatment and get more lime per dollar. Remember that often obsolete equipment can be scrapped and new equipment purchased with the saving, so why not have a modern plant at no extra cost?

IRON REMOVAL—SMALL SYSTEMS

By H. E. LORDLEY, Plant Manager

Department of Public Utilities, Richmond, Virginia

IN THE country today we have excellent large water purification plants with competent engineers and operators, yet in number these plants represent only a very small percentage of our water supplies. Thousands of small supplies having only a deep-well-pump and storage tank challenge the water works engineer with problems that must be solved with limited expenditures and with unskilled operating personnel. Of the many problems, economical methods of iron removal are of major interest.

Forms of Iron

Iron may occur in water either as organic iron, inorganic iron or a combination of both types. Ferrous bicarbonate is one common inorganic form of iron occurring in many supplies. Iron in combination with humic acid or other complex organic compounds may be classified as organic iron, and is usually found in wells located in swampy areas. It requires only a few simple tests, that anyone can run, even without laboratory facilities, to determine the type iron. Collect a sample and allow it to stand exposed to the air. Inorganic iron will precipate, leaving the sample cloudy. On the other hand, organic iron fails to precipitate and the problem of removal is more complex thereby.

Methods of Removal

Methods of removal may be classified as (1) Direct Chemical Reaction, (2) Coagulation, (3) Special Filters.

Under No. 1 we have aeration as the most economical method. Aeration requires only 0.14 parts of air per part of iron when carbon dioxide is not present. The iron is oxidized to insoluble ferric iron which precipitates and settles to the bottom of a tank or is removed by a standard sand filter. Frequently, this small amount of air can be introduced by some form of air pump or "sniffer" attached to the well pump. (2) In an open system a tray aerator followed by sand filtration removes the iron. Organic iron is combined chemically so that such a simple treatment will not break down the organic bond.

The second method involving direct chemical reactions utilizes chlorine for the oxidation of the iron instead of aeration. In addition, the chlorine treatment removes any troublesome sulfuretted hydrogen often found in conjunction with iron, and produces a sterile water having a definite residual chlorine. This is a cheap method since solutions of "Perchloron" or "H.T.H." are convenient sources of chlorine and can be applied to small supplies without difficulty.

Causitc Soda removes iron from water by raising the pH to range 8.0-10.0. At the high pH the oxidized iron precepitates as ferric hydroxide and is removed by settling or filtration. This treatment also has the advantage of removing free carbon dioxide and protects the system from corrosion.

Potassium permanganate has been used (3) to oxidize organic iron by first attacking the organic compound and allowing the iron to precipitate as hydrous ferric oxide or a combination of ferric iron and organic matter.

In this discussion of direct chemical methods, none of these suggested methods removed organic iron with any degree of success so that we use the old standby, coagulation with alum. Organic iron occurs in a colloidal state with humic acid, cellulose, and other end products of plant decomposition. Alum coagulation followed by filtration will remove this form of iron.

Contact Beds

Special filters, the third classification, are excellent in many cases and are very easy to operate. These filters are standard pressure filters, having a material of the same general characteristics of filter sand but impregnated with the higher oxides of manganese (MnO; Mn_2O_7). Water supplied to the filter must have an oxygen content equal to 15% of the soluble iron content for the oxidation process. The iron in the presence of oxygen and by the catalytic action of the manganese, is converted to insoluble iron and is removed by the filtering material. In backwashing, the precipitated iron is washed out and the filter is ready for use without regeneration. Occasionally the sand is treated with sodium permanganate to aid the catalytic action of the manganese. Even these filters fail to remove organic iron in some cases and should be installed only after analyses and surveys indicate that such contact materials will remove the iron.

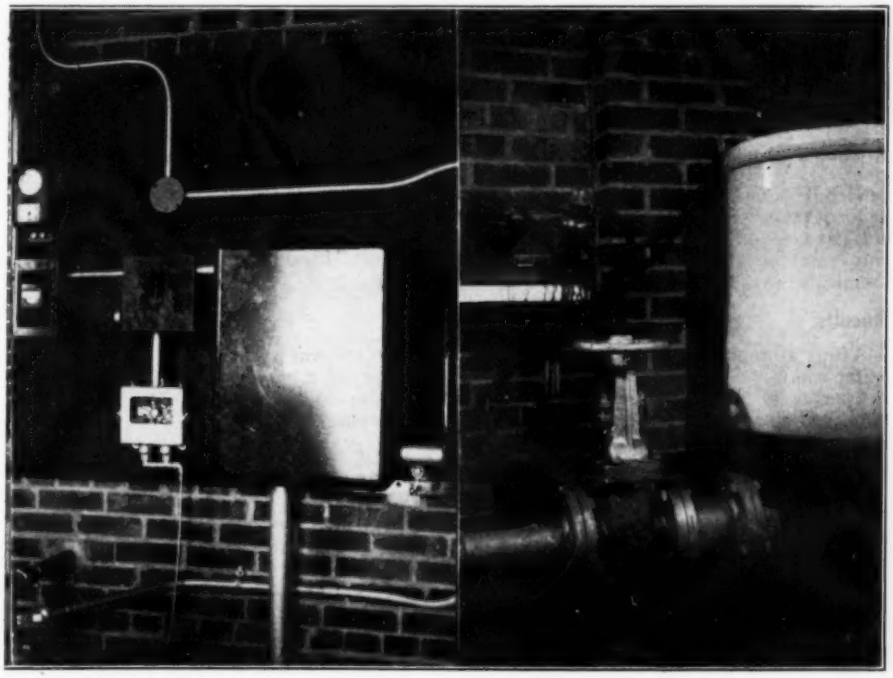
Ordinary sodium zeolite filters will remove iron by exchange as shown by the following reaction:

$$Na_2Z + MnO : Mn_2O_7 + 4Fe(HCO_3)_2 = Na_2Z + 3MnO_2 + Fe_2O_3 + 8CO_2 + 4H_2O$$

There are some plants that use one set of two of these filters to soften the water and another similar set to remove iron and manganese. Many different materials have been used in filters, from pyrolusite to coal, and new materials are coming into use in this very promising approach to iron removal each year.

A Case at Point

With this introductory discussion as a basis, several plants designed by Mr. M. C. Smith and the author will illustrate the practical application of these methods. The City of Richmond operates a deep water freight terminal below the City which has a domestic water supply from a 280 foot drilled well. Shortly after opening the terminal the domestic water developed bad tastes and odors and also deposited an iron stain on all the fix-



Control Panel
Time Switch, Magnetic Starter and Pressure Switch.

Double Duty Chloro Feeder
With 40-gal. crock of caustic soda and hypochlorite solution.

tures. Samples direct from the well and from the distribution system had the following analysis:

Table 1.

	At Well	*From Mains*
pH	6.0	6.4
CO_2	41	31
M. O. Alk.	40	65
Color	6	27
Turb.	1.5	3.0
Fe	10.0	8.0
H_2S	Present	None

When the samples were first collected the water was clear but after standing a few hours it became cloudy and indicated inorganic iron. After a few jar tests this theory was proved by the ease of oxidation with any of the direct chemical methods. Finally a combination treatment using both chlorine and caustic soda was selected for the job for the following reasons:

(1) The treatment removed ferrous iron in a heavy floc without the expense of aeration.

(2) Eliminated carbon dioxide and prevented corrosion.

(3) Eliminated sulfuretted hydrogen.

(4) Sterilized the water and gave a residual chlorine.

(5) The two solutions could be mixed in the same crock and fed through one feeder.

Elevated Tank as Settling Basin

The City had appropriated only $500 for the job, so we were forced to use the elevated tank as a settling basin and purchase only a heavy-duty Proportioneer's feeder, 40 gallon crock, time switch and a few lengths of pipe. The 30,000 gallon storage tank was of conventional design with a short riser pipe within the 36″ standpipe. This short riser-pipe was extended to about five feet above the bottom of the tank as shown in the accompanying sketch. Of course, this reduced the available water storage but furnished a settling basin in the bottom of the tank for the sludge, which settled so rapidly and completely that no filter was necessary.

In this system, as is true of other small supplies, little or no water was used after 9 p. m. so a time switch was adjusted to start both the pump and chemical feeder simultaneously at that time. This program also prevented untreated water from going into the system. A mercoid pressure switch in series with the time switch controlled the elevation of water in the tank. In this case the pump only operates a short time each night so the floc all settles before the draw comes on at 7 a. m., and gives a clear supernatant for consumption. About once a week the drain valve at the bottom of the standpipe is opened to remove the sludge from the tank.

The operating personnel could give the system only a weekly inspection and the chemical solutions were difficult to prepare in such a short time. However, in most cities some company manufactures liquid bleach and has a regular delivery system. In producing bleach 20% caustic soda is treated with chlorine to give a 15% available chlorine solution. In this case, the dealer delivered both 20% caustic soda and bleach direct to our 40 gallon crock. As the result the operators at the terminal did not have to prepare any solutions. In addition, the treatment was constant and the danger of inexperienced men handling chemicals was eliminated.

Results

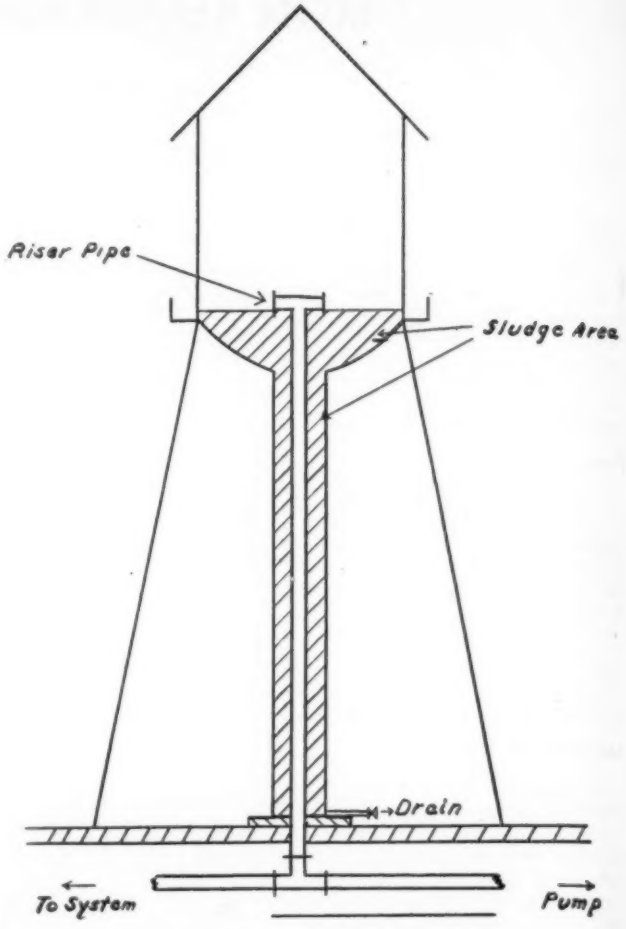
After a few adjustments and flushing of the system, the water was of excellent quality and could be used for all domestic purposes. Table 2 reveals the gratifying results with this treatment as evidenced by samples taken from the piping system.

Table 2

Dose. Caustic Soda 200 pmg. (100% NaOH) Chlorine 8.34 pmg.*

	(Before Treatment)	*(After Treatment)*
pH	6.4	9.0
CO_2	31	0
M. O. Alk.	65	110
Phenol. Alk.	0	7
Color	27	10
Turb.	3.2	0.60
Fe	10	0.01
H_2S	Present	None

*pmg. = pounds per million gallons.



Sketch of Converted Tank
Reveals simple changes made in extending the riser pipe and adding a tee to provide the shaded sludge separation zone. Accumulated but sterilized iron sludge is blown off systematically at the bottom of the original riser pipe.

Another Case

Never take iron for granted, for sometimes you realize that nature cares nothing for the theories of mankind.

Take for example a 284 ft. deep well only five miles from the above supply. Table 3 reveals the characteristics of its water.

Table 3
(Well No. 2)

pH	7.3
CO_2	9
M. O. Alk.	136
Color	28
Turb.	1.5
Fe	3.0
H_2S	Present

We expected this water to respond to the same treatment but after a series of jar tests we found that the iron was in the organic form and required an elaborate filter plant with chlorination, alum coagulation, settling, filtration and pH correction to give the same quality effluent as produced by the simple chlorination, alkalinization and settling plant. Only three miles from this supply another deep well needed only chlorination and settling in our special tank to give an excellent water, so you never know about the fallacies of water until an actual study is made of its amenability to a given treatment.

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(1) Negus, Sidney S., "The Physiological Aspects of Mineral Salts in Public Water Supplies." J.A.W.W.A. 30:242 (Feb. 1938).

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(3) McCrea, T. R., "Removal of Organic Bound Iron from Highly Colored Water." J.A.W.W.A. 25:931 (July 1933).

aids for water purification—PQ Silicates

ARE YOU looking for a way to improve the quality of your water supply? Try PQ Silicates as your coagulant aids.

Silicates, when converted into sols, increase the rate of growth of the floc as well as its size and toughness. Suspended solids are enmeshed in this floc which settles rapidly even in cold water. Thus water is clearer, with the filter capacity stepped up considerably.

Four methods for converting silicate of soda into useful coagulant silica sols are currently practiced. The choice of the reacting chemical (acid, ammonium salts, alum or iron salts) depends on the water and the sterilization method.

Our technicians are glad to consult with you on the proper converting procedure for your water supply and to arrange for a test.

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Bulletin No. 52-5. Colloidal Silica as an Aid to Floc Formation.

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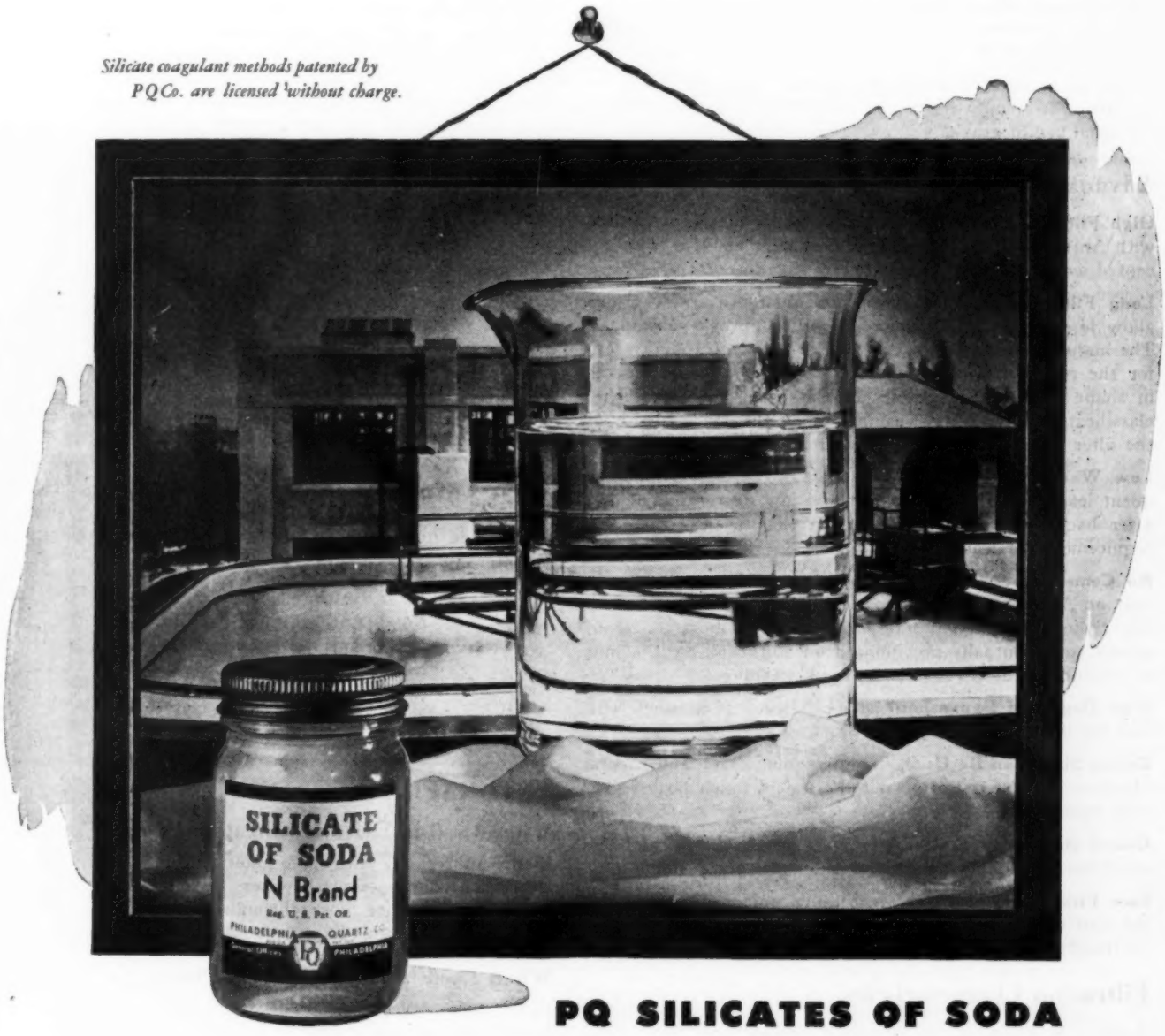

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THE ANTHRACITE EQUIPMENT CORP.

101 Park Avenue
NEW YORK CITY, N. Y.

ANTHRAFILT — an Improved Filter Medium

Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

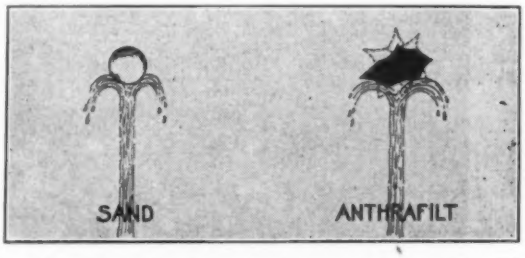
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effectixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

ANTHRAFILT AND ITS SIGNIFICANCE*

By H. G. TURNER
Research Engineer, Anthracite Equipment Corp.

ANTHRAFILT is a filter medium made from Pennsylvania anthracite. The first step in its preparation is the selection of a type of raw material which will provide a particle free from small fracture cracks and possessing the best form. This particle must be strong enough to withstand years of backwashing without breaking into smaller grains and should be sharp, angular and flat.

After the highest quality of raw coal is selected it is sent to the breaker where it is crushed, thoroughly washed and cleaned by gravity separation methods which free it from slate and associated non-coal mineral substances. The crushed material is finally screened over vibrating screens equipped with jets of water which assist in producing the desired size and remove, as far as possible, all very fine particles.

No one standard size is made in the screening process. Instead, different sizes are made to meet the various conditions of water treatment, water characteristics, filter design and filter operation. Information as to the best size for a given installation is obtained through a questionnaire sent to each purchaser. The purchaser who has had no experience with Anthrafilt should accept the specifications of the manufacturer regarding the proper size to be used. The manufacturer can make one size as cheaply as another so has no reason, other than the satisfactory operation of filters, to recommend one size in preference to any other. No filter expert, regardless of his years of experience or standing in the profession, can say with assurance what size Anthrafilt should be used in a filter unless he has conducted his own tests on this material under proper conditions in the laboratory or in the field. The reason for this will be made clear as this thesis is developed. These remarks all apply to the sand-size Anthrafilt. The sizes that are used in place of gravel are made to standard dimensions and are used in much the same way as gravel.

Properties of Anthrafilt Versus Sand

Sand is composed almost entirely of silica. It is insoluble in most acids but is soluble in alkalies. Its specific gravity is 2.65, and weight approximately 100 lb. per cu. ft. The particle shape is commonly rounded.

Anthrafilt is composed of carbon plus a small percentage of ash-forming mineral matter. It is not soluble in common acids or alkalies. Its specific gravity is 1.60 and weight approximately 50 lb. per cu. ft. The particle shape is sharp, angular and flat.

While it is true that silica sand and Anthrafilt have many other characteristics than those given, these are the ones of greatest significance in their contrasting behavior in filters.

Filters act both as strainers and as entrapping agents. Where no coagulant is used, the strainer action predominates. Where coagulants are used, entrapment predominates. Since the degree of entrapment is directly proportional to the surface area of the filter medium, the angular particle of Anthrafilt is more efficient than the same sized sand having a spherical shape, because an angular grain has a greater surface than a sphere of the same volume.

In practice, this means that a coarse Anthrafilt particle will give the same degree of turbidity removal as a relatively fine sand. This is important when one considers that a coarse filter medium, in contrast to a fine one, will give longer runs between backwash periods, will not clog as readily with algae, will develop lower head loss, will permit higher rates and will be cleaned more thoroughly when backwashed.

Since coarse Anthrafilt (±0.75 mm. effective size) is as efficient as fine sand (±0.40 mm. effective size) in turbid matter removal and since it weighs half as much, it can be substituted for fine sand without sacrificing the quality of effluent and without detracting from a high degree of filter bed expansion when backwashed with the same velocity as used with fine sand.

Users of Anthrafilt have found that it is more readily cleaned under routine backwashing. This has been strikingly demonstrated by Paul Weir of Atlanta, Ga., who made intensive turbidity determinations on the wash water discharged to sewer in the case of parallel experimental sand and Anthrafilt filters. In every determination the turbidity of the waste water from the Anthrafilt filter was higher than it was in the sand unit. This behavior is partly due to the particle shape and partly due to the composition of the Anthrafilt grains. Because of its dominant carbon content, Anthrafilt does not react chemically with the turbid matter which envelops the grain during filtration. Hence it not only releases common dirt easily but also does not become badly coated with lime, manganese or iron. With proper filter design and operation it will not coat even where lime-soda softening is used and only very slightly in iron removal filters.

Where the hot-process, lime-soda softening is used, Anthrafilt,[1] after the first few days of operation, will contribute no silica or other mineral matter to boiler feed water. Sand, on the other hand, will release silica to the water flowing through the softening unit.

The properties of Anthrafilt have made it very effective in filters of all kinds—filters for removal of oil, boiler treatment filters, swimming pool filters, chemical filters, iron removal filters, sewage filters, portable filters where light weight is important, and municipal filters of gravity, pressure or slow-sand type.

Historical Data

The first filter for clarification of municipal water was a slow sand filter built in London, England, in 1829. This filter was cleaned by scraping the surface and removing the upper portion of the sand for washing. In 1856, Tours, France, built the first filter to be backwashed. Since it was impossible to obtain enough pressure to lift the sand, this system of cleaning was abandoned.

The rapid filter was an American invention which was installed in industrial plants around 1883. This type of filter was first employed in the treatment of a public water supply at Somerville, N. J., in 1885. Up to this time little attention had been given to coagulation. From 1885 on the use of coagulants became a widespread practice. Sedimentation basins were given no serious consideration until several years after coagulation came into the picture. In all early filters the efficiency of the units was rated on bacterial removal. Chlorination had not yet become a recognized practice. Sand sizes, filter depths and filtration rates were all designed to give a clear water under these crude conditions of water treatment and filter design.

This historical sketch is cited to show that we may have inherited rules and regulations which no longer apply in view of filter improvements in many directions. The most outstanding relic of those early days is the commonly accepted filtration rate of 2 gpm. per sq. ft. for rapid filters. There have been great improvements in sedimentation basins, coagulation, chlorination and filter design, and yet the presently accepted filtration rate is the same as it was in the days before coagulation, chlorination or sedimentation. This does not seem logical.

There is adequate evidence that a filtration rate considerably in excess of 2 gpm. per sq. ft. is possible. As far back as 1898 Fuller reported successful filter operation at rates as high as 3 gal. In his "Report on Investigations Into the Purification of the Ohio River Water at Louisville, Ky.," he states: "But it is probable, in view of the results of the Western pressure filter, that in practice under favorable conditions the plant could be operated so as to make increased (uniform) rates in a measure meet increased demands for filtered water." In the same report he states further: "In all these systems the provision for subsidence, both with and without coagulation, was thoroughly inadequate."

As an example of more recent evidence, it has been reported that a total 4-gal. rate is used through sub-surface as well as surface filtration at the Kenilworth, Ill., filter plant.[3] While the rate is 2 gal. through the top of the filter and an added 2-gal. sidewise rate below the upper 2 in., the total vertical rate for the lower half of the filter is 4 gpm. per sq. ft.

About 1940 the Lansing filtration plant[3] was operating at a 3-gal. rate. The St. Louis (Howard Bend) plant is also designed to operate at a 3-gal. rate. The most recent installation is the new Chicago filtration plant[4] designed to operate at a 4-gal. rate during the summer and a 3-gal. rate during the winter. In addition, many plants are operating more or less subrosa at a 3-gal. rate.

In all the recent filtration plants designed to operate at higher than a 2-gal. rate, flocculators are used and some form of agitation or surface wash is used in the filters. Furthermore, at these plants more than average attention is given to the formation of a large, or at least a tough, floc particle.

The Part Played by Anthrafilt in Increasing Filter Capacity

The first municipal filtration plant to increase its capacity through the use of Anthrafilt was the Passaic Valley Water Commission plant at Little Falls, N. J.[5] Fig. 1 shows how the

*Published in the *Jour. A. W. Wks. Assn.*, 36, 431 (1944). Reprinted by permission of the Association.

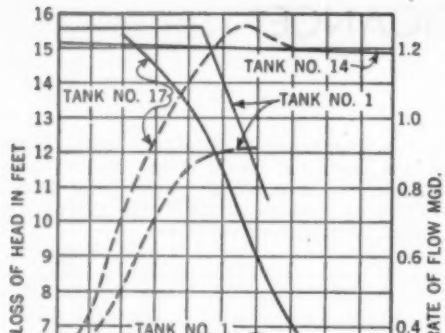
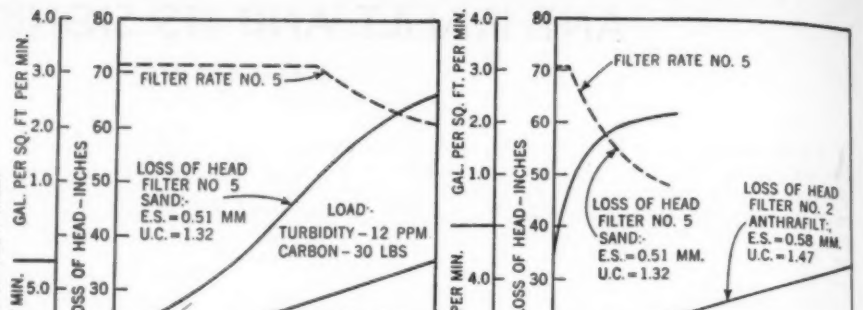

LOSS OF HEAD IN FEET
RATE OF FLOW MGD.
TANK NO. 14
TANK NO. 17
TANK NO. 1
TANK NO. 1
AFTER OVERHAULING
TANK NO. 14
HOURS ELAPSED AFTER WASHING
FILTRATION RATE —— LOSS OF HEAD - - - -

*Fig. 1. The First Municipal Filtration Plant (Passaic Valley, N. J.) to Use Anthrafilt to Boost Its Filter Capacity Showed a 50 Per Cent Increase.**


GAL. PER SQ. FT. PER MIN.
LOSS OF HEAD - INCHES
FILTER RATE NO. 5
LOSS OF HEAD FILTER NO 5 SAND:- E.S. = 0.51 MM U.C. = 1.32
LOAD:- TURBIDITY - 12 PPM CARBON - 30 LBS
LOSS OF HEAD FILTER NO. 2 ANTHRAFILT:- E.S. = 0.58 MM U.C. = 1.47
FILTER RATE NO 2
HOURS OPERATED
FILTER RATE NO. 5
LOSS OF HEAD FILTER NO. 5 SAND:- E.S. = 0.51 MM. U.C. = 1.32
LOSS OF HEAD FILTER NO. 2 ANTHRAFILT:- E.S. = 0.58 MM. U.C. = 1.47
FILTER RATE NO. 2
LOAD:- TURBIDITY - 12 PPM. CARBON - 50 LBS.
HOURS OPERATED

Figs. 2-3. Better Than a 3-Gal. Rate Is Maintained for 24 Hr. by Anthrafilt Units at Wilkinsburg, Pa.†

capacity of these filters was increased at least 50 per cent. The solid lines indicating the filtration rate show that Anthrafilt in tank No. 14 maintains its rate with little change over the full length of run, while in the sand tanks Nos. 1 and 17 the flow drops off rapidly within 2 to 4 hr. Air wash was used in these filters. The next municipal plant to use Anthrafilt to increase plant capacity was New Toronto, Canada, where capacity has been increased 100 per cent. At about this time the plant capacity of Oklahoma City, Okla., was increased from 16 mgd. to 30 mgd. by substituting Anthrafilt for sand.

Within the last year the Pennsylvania Water Co. at Wilkinsburg, Pa., because of excessive war demands, was forced to increase its capacity (Figs. 2 and 3). It will be noted that better than a 3-gal. rate is maintained for 24 hr. by the Anthrafilt units but it decreases rapidly in the sand units. With the filters not greatly loaded (Fig. 4) both Anthrafilt and sand hold their higher rates for the duration of the run although the Anthrafilt develops a much lower head loss. Palmer filter agitators were used.

Figs. 5 to 8 are photographs of 7-day loss-of-head charts from the filters of the city of Buffalo, N. Y. It will be noted that the Anthrafilt filter (Fig. 5) shows a filter wash once during the week; the sand filter (Fig. 6) shows two washes during the week. In Fig. 7 the Anthrafilt filter had to be back-washed twice a week during the algae season while the sand filter (Fig. 8) had to be washed 14 times. Palmer filter agitators were used in the Anthrafilt filter.

Many industrial plants have increased their filter capacity through the use of Anthrafilt plus recommended mechanical alterations. The best example of what has been done in an industrial plant is the experience of the Hammermill Paper Co. at Erie, Pa. A few years ago they doubled the capacity of their filters by changing from sand to Anthrafilt and installing Palmer filter agitators. This industrial plant is chosen because they filter 25 mgd. as compared with 30 mgd. for the entire city of Erie (population 127,000) and because they make a product of such high quality that their water must be close to perfect.

The author is firmly convinced that any filtration plant that is now operating at a rate of 2 gpm. per sq. ft. can increase its capacity by 50 to 100 per cent by taking one or all of the following steps:

1. Conduct laboratory tests to determine what kinds and what amounts of chemicals are necessary to secure the best floc under all conditions.
2. Make provision for quick mixing of chemicals with raw water.
3. Use pre-chlorination.
4. Improve flocculation by installing flocculators.
5. By means of floats or color solutions, test basin to locate short circuits. Install or remove baffles to counteract short circuits.
6. Compensate for reduction in sedimentation time and hence overloaded filters by installing surface wash if other forms of adequate sand surface agitation are absent.
7. Change from fine sand to coarse Anthrafilt of the proper size to meet the conditions. Coarse, water-worn sand will not be effective. Crushing vein quartz might work but it would require twice the wash-water velocity for backwashing.

In general, filter runs between washes should continue as long as a satisfactory effluent is produced but not beyond a period where the filter can be cleaned by backwashing. Anthrafilt will give filter runs at least twice as long as sand and still not load the filter to a point where it cannot be cleaned by backwashing. Georgia[8] obtained experimental runs of 300 hr. in an Anthrafilt unit at the Cornell University filtration plant. He says, however, that "...it is not believed to be good practice to put this much load on the filter. Runs have now been reduced to one week and they may be cut even more if future operation makes this seem desirable." There are probably many filtration plant superintendents who would not complain if their filter runs were reduced to one week.

Loss of head is a convenient indicator that a filter has run long enough. It should be correlated, however, with the quality of the effluent and conditions of filter, and should not be used as an arbitrary figure. The loss of head in Anthrafilt is rarely over 4 to 5 ft., whereas sand filters, under the same conditions other than filter medium size, will show a head loss of 9 ft. or more.

Size of Filter Medium and Filter Depth

One of the best papers on this subject was prepared by Thomas M. Riddick.[7] Much of the value of his paper is found in a discussion by several experts. In the same Journal is a paper by G. B. McCall, S. E. Edwards, and Edward S. Hopkins.[8] After reading these papers one can arrive at as many different conclusions as a handful of citizens interpreting a paragraph

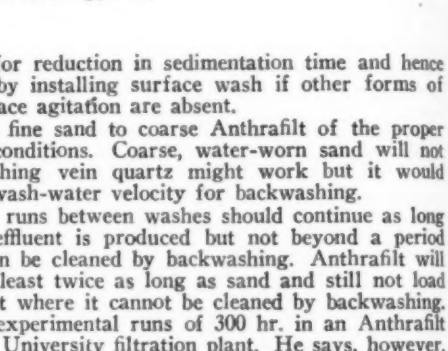

GAL. PER SQ. FT. PER MIN.
LOSS OF HEAD - INCHES
FILTER RATE NO. 5
LOSS OF HEAD FILTER NO. 2 ANTHRAFILT:- E.S. = 0.58 MM. U.C. = 1.47
LOSS OF HEAD FILTER NO 5 SAND:- E.S. = 0.51 MM. U.C. = 1.32
FILTER RATE NO. 2
LOAD:- TURBIDITY - 12 PPM.
HOURS OPERATED

Fig. 4. Filters Are Not Heavily Loaded Both Anthrafilt and Sand Hold Higher Rates for Duration of Run at the Wilkinsburg Plant.†

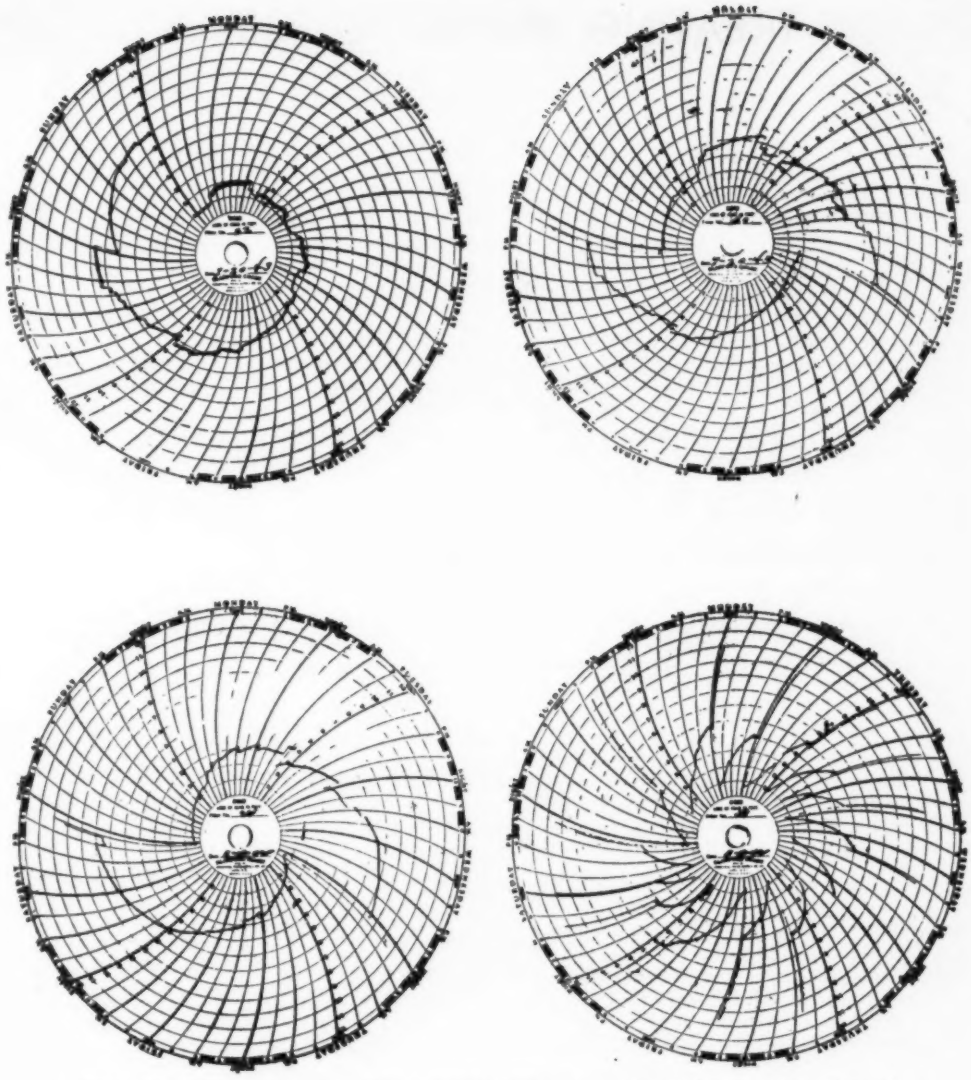
*Courtesy Arthur T. Cook, Gen. Supt. and Engr., Passaic Valley Water Com., Paterson, N. J.
†Courtesy R. B. Adams, Chief Chemist, Pennsylvania Water Co., Wilkinsburg, Pa.

in a standard government order. One thing on which the authors agree is the importance of proper conditioning of water for filtration. This is important because the selection of sand or Anthrafilt sizes and depths, to meet the worst conditions during the year, may impose expensive operation costs for 350 days of that year.

Another cause for confusion in such discussions is an attempt to supply small laboratory filter results to actual large filters or to apply findings from a filter of one type to one of different design. If these results are related to a large filter using high-velocity wash and high freeboard, they will not apply to a filter without troughs or low freeboard or to low-velocity wash plus agitation during washing.

In our own experimental work with Anthrafilt and sand it was found that a flat, angular grain was more effective in turbidity removal than a rounded grain. We agreed with all other investigators that the deeper the filter the coarser the filter medium could be. In applying our results it was decided that particle size and filter depths should be specified to suit the conditions of treatment, filter design and filter operation of each plant in question.

In most of our installations the Anthrafilt has an effective size of 0.70-0.73 mm. and a uniformity coefficient of less than 1.60 with a filter depth of 30 in. When a depth of 18 to 20 in. is all that can be placed in a filter the size is decreased to 0.58-0.62 mm. effective size. Where depths greater than 30 in. are available the size is increased accordingly. These general measurements are often modified to meet special conditions.



Figs. 5-8. Charts Show 7-Day Loss-of-Head From the Filters of the City of Buffalo, N. Y. (Courtesy Henry Wagner, Chief Chemist, Div. of Water, Buffalo, N. Y.)

Filter Wash—Length and Strength

Fixing a length of time for filter washing is like fixing a length of time for washing hands. Three minutes may be plenty for hands that rock the cradle but entirely inadequate for hands that grease motors. Filters should be washed long enough to clean them—which means a short wash if they are not very dirty and a long wash if they are filthy.

The wash water velocity required to clean a filter should be high enough to give nearly 50 per cent expansion if water wash from below is used exclusively. If adequate agitation during washing is available, a low-velocity wash is effective and of course a relatively low expansion of filter bed.

Anthrafilt filters are usually washed with a 24-in. rise during the winter and a 30-in. rise during the summer. Where filter agitation is available, wash water velocities of 18 in. rise per minute, even for the coarsest material, have been found adequate. There will be no greater loss of Anthrafilt than of sand during the life of a filter. While Anthrafilt is half as heavy as sand, the weight of the individual particle is not half that of ordinary sand because a coarser particle of Anthrafilt is used.

One cause of dirty filters is the feeling that it is a disgrace to lose filter medium. A plant may use several carloads of alum per year without disturbance and yet if a little sand is washed from the filters it is the basis for criticism. The filter operator is usually instructed to use great care in washing the filter so as to lose no sand, and, as a result, commonly underwashes. If he were instructed to be certain to wash filters so as to lose 5 per cent of the sand per year, the filters would be kept in a much cleaner condition. Two filtration plants in a large industrial city may be cited as examples: At one plant no sand has been purchased for 23 yr. and the filters are full of mud and cracks. At the other plant one carload of sand is purchased each year and the filters are very clean. Where filters are provided with means for effective agitation of the material during backwashing, no sand loss is likely to occur.

Summary

Since Anthrafilt is essentially a carbon, and hence more nearly chemically inert than any other filter medium, it is well suited for many filtration processes. Its conchoidal fracture produces a particle which has the most desirable shape for use in filters; its low specific gravity and angular shape makes possible longer filter runs and more effective filter washing at lower backwash rates. Filter capacities have been increased from 25 to 100 per cent through the use of Anthrafilt.

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TREATING WATER TO PREVENT CORROSION

By JOHN R. BAYLIS

Associate Editor, Water Works & Sewerage

The writer, in 1930 presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_2 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

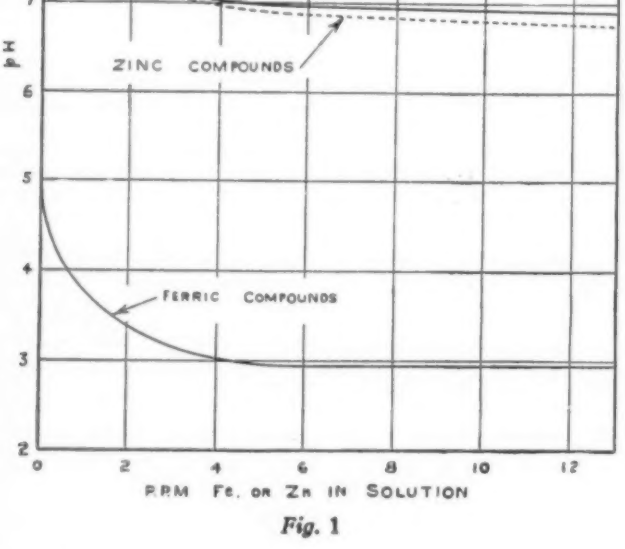
SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M. Fe. OR Zn IN SOLUTION

Fig. 1

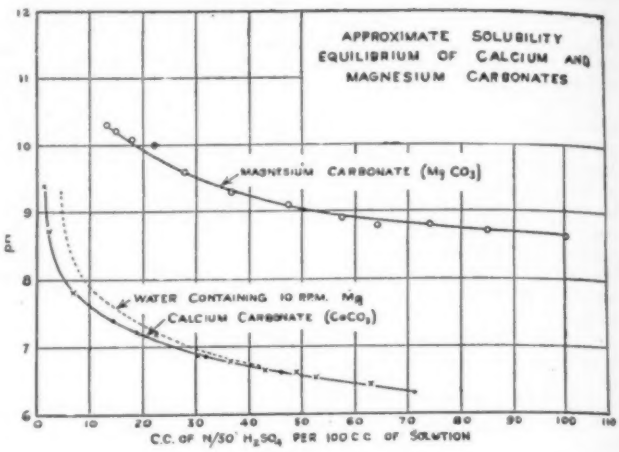
APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($MgCO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/30 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually design the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

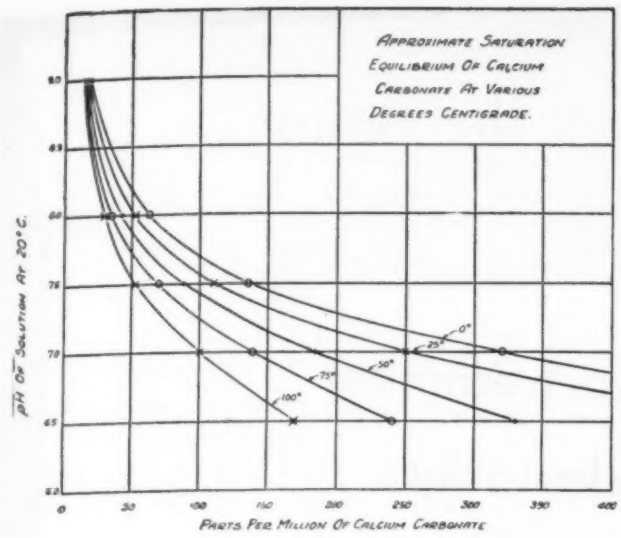

Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_2 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_2 is present. This was due to the CO_2 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the percipitate. It will remain where it is precipitated to offer protection against further corrosion.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

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[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. Water Works Engineering, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines. Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

Report by the Army

Hexametaphosphate treatment has been used satisfactorily at ninety-two posts

The Army wants its hot water hot — 180°F. minimum is specified for washing dishes. Heaters operating at the higher levels necessary to deliver water in the mess halls at this temperature naturally scaled up or corroded out at an extreme rate.

Post engineers seeking an answer to their mounting difficulties back in 1941 turned to Calgon* for help. Simple and straightforward treatment with a few pounds of Calgon kept heaters on the line continuously for many months instead of a few days, cut down losses of critical equipment at a time when every pound of metal was precious.

Now the Army in a recent survey of its installations in this country, finds 92 posts where Calgon is relied upon to do at least one of the three jobs it does so effectively:

1. *Prevent scale*
2. *Prevent "red water"*
3. *Control corrosion*

Calgon pioneered these developments. Today, in war industry, as in Army camps, unadulterated Calgon made from food-grade phosphoric acid is doing an outstanding job in solving water problems.

Calgon is the registered trade-mark of Calgon, Inc., for its glassy sodium phosphate products.

HAGAN HALL BUROMIN CALGON

calgon, inc.

A SUBSIDIARY OF HAGAN CORPORATION

HAGAN BUILDING PITTSBURGH 30, PA.

CALGON TREATMENT*

As Applied in Water Quality Control for the Solution of Four Problems

By OWEN RICE
Calgon Inc., Pittsburgh, Pa.

CALGON is a molecularly dehydrated, glassy phosphate commonly known as hexameta-phosphate and usually given the formula $(NaPO_3)_6$. It is easily dissolved and fed by any solution feed device. For the past ten years it has been of interest and of increasing importance in many phases of water treatment. Its use in several hundred plants during the last six years has shown that the continuous application of small amounts of Calgon to municipal water systems overcomes many of the problems commonly encountered.

Calgon prevents the precipitation of calcium carbonate from lime or lime-soda softened water as well as from hard waters high in bicarbonate alkalinity. Its addition to well water prevents the precipitation of dissolved iron therefrom, while its addition to any water reduces corrosion throughout the system. At first glance, these various applications and effects do not seem related but the result obtained in each case appears to be due to the adsorption of the Calgon on the surfaces of the metals, their metallic salts and oxides involved.

Stabilization of Water After Lime or Lime-Soda Treatment

After-precipitation of calcium carbonate from lime or lime-soda softened water has been a problem ever since the first softening plants were placed in operation. Although after-precipitation can be prevented more or less completely by recarbonation, the limits between which such a treatment must be maintained are very narrow and, although scale may be prevented in this manner, corrosion often results particularly in hot water heaters.

The addition of 1 or 2 ppm. of Calgon completely prevents after-precipitation from lime or lime-soda softened water.[1] It is believed that the metaphosphate is adsorbed on the crystal nuclei of calcium carbonate as rapidly as they form in the water, thus isolating each nuclei from further contact with the water and preventing its growth. This property of Calgon brings about the stabilization of a supersaturated water, from which calcium carbonate would otherwise precipitate.

The addition of Calgon to the water passing to the filters will keep the sand and underdrainage system free from incrustation. In cases where the additional softening effect obtained by the removal of some of the hardness on the filters is desired, the metaphosphate should be added to the clear well. Stabilization with Calgon will result in mains, meters, and hot water systems remaining free from calcium carbonate scale.

Precipitation of $CaCO_3$ from Hard, High Bicarbonate Waters

Calgon has the same stabilizing effect on waters which are naturally hard and high in bicarbonate alkalinity. Where ordinarily the loss of CO_2 or an increase in temperature would cause the formation of scale, this deposition is prevented by the presence of small amounts of Calgon.

Calgon treatment has proven entirely successful in preventing scale formation in hot water heaters with waters up to 1400 ppm. hardness and 600 ppm. bicarbonate, and at temperatures up to the atmospheric boiling point. At the most, an addition of 3 ppm. is required while, under less severe conditions, 2 or even 1 ppm. has proved sufficient.[2]

Preventing Dissolved Iron Precipitation

The action of Calgon on iron in solution is akin to that with calcium carbonate. Precipitation is prevented, thus eliminating "red water." In order to obtain this action, it is necessary to add the Calgon before the iron has had any chance to come into contact with the air. Therefore, in the case of well water supplies it is always best to add the Calgon at the suction side of the pump.

The addition of Calgon in a ratio of 2 ppm. of Calgon for each ppm. of dissolved iron is sufficient to hold the iron in solution even when the water is later aerated or chlorinated.[3]

Corrosion Control with Metaphosphate

Metallic iron when exposed to water dissolves to a considerable extent. Any method of corrosion control depends, therefore, on the formation of an insoluble coating on the surface of the metal.

As mentioned above, Calgon has the ability to coat out on metal or metal oxide surfaces. As the metaphosphate is adsorbed on the iron surfaces of the mains in a distribution system, it forms an iron phosphate film which effectively seals the metal from the water. This film is formed at all pH values above 5.0 so that when using Calgon it is not necessary to add any additional chemicals to change the pH. Also since the film is formed by adsorption and not precipitation, the coating is formed throughout the entire system and not just near the plant.

The addition of Calgon in decreasing corrosion is in no way due to reaction with the water. The water simply acts as a carrier to bring the Calgon in contact with the metal or oxide surface upon which it is adsorbed. Since it is the adsorption of the metaphosphate on the surface of the metal which prevents corrosion, the necessity of supplying sufficient Calgon to meet the requirements of the system is obvious. This can be done either by using a relatively high concentration of Calgon in a small quantity of water or lower concentrations in larger quantities of water. This latter condition is the one which exists in all but the smallest municipal water systems.

In cases where corrosion is severe, it has been found that high initial feeds of Calgon—5 to 10 ppm.—are very helpful in more promptly forming the protective coating in the system. After equilibrium has been reached and the protective coating has been formed, the Calgon can usually be reduced to very small amounts, 1 to 2 ppm., and still be sufficient to maintain the protective coating initially formed.[4]

Summary

Calgon is easily dissolved and fed by any liquid feeding device. It is inexpensive because of the small quantities required and is easy to control. It has proven entirely successful when used in each of the above mentioned applications. Excellent results have been obtained in preventing the after-precipitation of $CaCO_3$ from lime or lime-soda softened water. Hot water heaters are being kept free from scale when hard high bicarbonate waters are used. Dissolved iron has been kept in solution, and the film of metaphosphate formed on the metal surfaces in the system has successfully prevented corrosion and all at concentrations of only a few ppm.

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[*A summarial statement prepared for the Reference and Data Section of "Water Works and Sewerage" by Mr. Rice at our request.—*The Editors.*]

OPERATING LOGS FOR SMALL WATER PLANTS

IN MOST states the department of health requires that monthly records of operating and analytical data be forwarded to the state office and forms are provided for that purpose. In cases where such forms are not provided or where the individual operator desires to keep his own record it may be desirable for the operator to develop a form. Herewith as a guide are three examples of forms used by three different state departments of health.

Concerning the need for and use of operating logs of this type, Charles R. Cox, Chief, Bureau of Water Supply, Division of Sanitation, N. Y. State Dept. of Health, says, "One is likely to neglect the maintenance of records unless their true significance is realized. Actually they represent a summary of work accomplished and of results secured, and, therefore, serve as a guide to future action as well as a proof as to the quality of water delivered in the past. Such records also furnish local and state departments of health with a summary of prevailing conditions for their guidance in the general supervision of public water supplies insofar as the health of the consumers is concerned.

"Actual experience has indicated that well maintained and complete records have enabled water supply officials to demonstrate to epidemiologists studying an outbreak of disease, which is suspected to be water-borne, that the operation of their plant was satisfactory and that water of safe sanitary quality was delivered during the period of onset of the disease. In the absence of such complete records, the scattered distribution of cases might implicate the water supply as being the obvious factor in that it is usually common to all of the cases. The importance of the situation is that evidence could not be confuted in the absence of records as proof of the satisfactory quality of the water delivered during the critical period in the past. Note the significance of the phrase 'in the past,' because no amount of analytical work during an epidemiological investigation can disclose the quality of water long since consumed in the municipality before the onset of the epidemic.

The Chief Value of Log Keeping and Records

"This more obvious value of records of past accomplishment, however, should not submerge the chief value of appropriate records for the guidance of the operators themselves. The mere recording of summarized information by an operator results in his own appraisal of his work, which otherwise might not be considered in such an abstract manner, and the maintenance of records encourages keener observation of operating conditions, frequently resulting in economies along with improved results. Records would be of limited value unless they are used as a basis of judgment and to stimulate keener observation. For example, the mere recording of water temperature in and of itself is of little value, but if the operator knows from past records that when water temperatures are below, say, 39° F., the entering water tends to stratify and flow along the bottom of coagulation basins, thus leading to short circuiting and agitation of previously deposited sludge, the temperature observation becomes of paramount importance. In the same way previous temperature observations may indicate proper coagulation operations technique, or cold weather modifications in filter washing technique. These record blanks are not merely a collection of figures but are summaries of observations which are definitely related to experience and thus serve as guides to future action.

"The basic characteristic of the typical record blank should be the provision for recording three groups of observations: first, plant operating details; secondly, doses of various chemicals used, and thirdly, results of tests as to the character of the water being treated and of the final effluent produced.

Value of Operator's Diary

"The monthly record blank should be supplemented by a diary and the conventional bookkeeping records as to expenses incurred in the operation of a treatment plant. A simple diary is of fundamental value for recording intangible and frequently highly personal items which may be so obvious at the time that their future value may be overlooked. Such information, however, is soon forgotten or becomes sufficiently vague to be of little value unless brief informal notes can be consulted. Diary records are of special value when they indicate procedures followed in solving unusual problems.

"In summary, a habit of mind should be cultivated of viewing the readings of meters, gauges and other instruments and also the results of laboratory tests as visible evidence of what otherwise is not apparent to the operator and for such observations to be recorded for convenience in appraising their joint significance and to serve as a guide for the future."

Patterns of Record and Log Forms

The New York State form is made to fold in the middle to produce a file size of 8½ by 11 inches. In Fig. 1 is shown half of this form covering mainly plant operating data, chemicals used, and some analytical results. The other half of the form (which we regret could not be reproduced because of space limits) contains columns for recording pH, total bacteria and coliform bacteria in the raw, filtered and chlorinated water. On the back of the form are spaces for additional analytical data collected during the month to show the character of water delivered to the consumer or to give more information concerning unusual conditions at the plant. Items included are turbidity, color, odor, hardness, alkalinity, iron, manganese, chlorides, residual chlorine, dissolved oxygen, and oxygen consumed.

Fig. 2 shows a similar form used in the state of Ohio. This form contains more analytical data and fewer entries of plant

To New York State Department of Health:

Report on Operation of WATER PURIFICATION PLANT at ..... for Month of ..... 193.....

Date	Water Treated 1000 gallons	Filters		Wash Water		Alum	Lime	Soda Ash	Carbon	Ammonia	Chlorine				Temperature	Turbidity p. p. m.		Color p. p. m.		Odor	
											Pre.		Post.								
		Units in use	Units washed or scraped	Total 1000 gals.	Length of wash min.	Lbs. per day	Lbs. per day	Lbs. per day	Lbs. per day	Lbs. per day	Lbs. per day	Resid. Chlor.	Lbs. per day	Resid. Chlor.	Raw Water	Raw	Filt.	Raw	Filt.	Raw	Filt.
	1	2	3	4	5	6	7	8	9	12	13	14	15	16	17	18	19	20	21	22	23
1																					
2																					
3																					
30																					
31																					
Total																					
Aver.																					

48 REMARKS: Filters out of service; complaints (Nature, cause, remedy); Results of microscopic examinations; Etc.

	Date	
Sedimentation Basin last cleaned		
Clear water Basin last cleaned		
Storage Reservoir last cleaned		

Fold Here

Fig. 1. First Half of Monthly Operating Log and Report Sheet of the New York State Health Dept. (This half contains all data on plant operation and chemicals used, etc. Elsewhere in the form are columns for pH and total and coliform bacteria in raw, filtered and chlorinated water.)

Report of Operation to the Department of Health, State of Ohio, for Water Purification Plant at ____

DATE	WATER TREATED Thousands Gallons	FILTER OPERATION: Number Used	Filter Hours	Length Runs	Number Washed	CHEMICALS USED Gr. per Gallon: Alum	Lime	Soda	Parts per Million: Carbon	Ammonia	Chlorine	CHEMICAL RESULTS IN PARTS PER MILLION: Turbidity Raw	Turbidity Applied	Alkalinities Raw M.O.	Settled M.O.	Settled Phenol	Carbonated M.O.	Carbonated Phenol	Filtered M.O.	Filtered Phenol	Hardness Non-Carbonate Raw	Non-Carbonate Filt.	Total Raw	Total Filt.	pH Raw	pH Filt.	Color Raw	Color Filt.	Magnesium Raw	Magnesium Filt	Residual Chlorine Plant Tap	Residual Chlorine Distribution
1																																
2																																
3																																
30																																
31																																
Totals																																
Avg.																																

Percent Wash Water Used During Month _____

Cost of Chemicals per Million Gallons _____

Month _____ Year _____

_____ Supt.

_____ Operator

Fig. 2. Form of the Ohio Dept. of Health for Water Plants. (Showing operating data, chemicals used, and analytical results.)

operating data and chemicals used. This form is augmented by a second, on which is entered all of the bacteriological test data. The Ohio Department of Health also has a third form used only for zeolite water softening plants. The general idea of this latter form is a combination of the other two with only columns pertinent to water softening included.

Concerning these forms, Thomas R. Lathrop, Assistant Engineer of the Ohio State Department of Health, writes, "Some of the larger plants keep more complete data on operation in their own files. For smaller plants, however, the data covered by these forms are sufficiently comprehensive. Sometimes it is necessary to change column headings to fit special conditions. All forms are 8½ by 11 inches, which is good filing size. Operating log forms are not a fixed standard and often find need of revision at intervals, perhaps to add a new test or delete an old one. Climatological and water temperature data should be included at every plant. Not many plants use all of the columns provided on the Ohio forms, and hence by change of heading may add some test or observation not included."

Fig. 3 shows a typical bacteriological data log and report sheet as used by the Illinois Department of Health. In addition to this form there are three other forms of the same size (9¼ by 14½ inches), and these forms record data similar to that given in Figs. 1 and 2 (the New York and Ohio forms).

About these Illinois forms, William J. Downer, Acting Chief Sanitary Engineer of the Illinois State Department of Health, writes, "The form containing the plant operating, chemical operating and analytical data is used for surface water supplies having conventional treatment and for lime-soda water softening regardless of whether a ground or a surface supply. Another similar form, with slightly different entries, is used for ground water supplies when iron removal, zeolite softening or a combination of the two is involved. Another form records information on well supply plants that have no treatment but chlorination. It was designed chiefly for use in state institutions but has found favor in several public water supply plants. On it are recorded hourly residual chlorine determinations daily, weight of chlorine cylinder, and amount of chlorine used each day as well as volume of water treated each day."

In General

In the preparation of any form, certain ideas and factors should be borne in mind. Size of sheet and ease of filing for ready reference, columnar headings only for items requiring regular entry, provision of an extra blank column or two for miscellaneous data or results, and a column for remarks. (The latter were trimmed out in the accompanying cuts in order to preclude too great a reduction and to conserve space.) Provisions for all data and entries which may properly be included under the three categories of data, set up above, should be made. The columnar headings should be self-explanatory and separated by vertical lines of varying weight to segregate related data into sections. Other general ideas expressed by A. A. Hirsch on a log for a sewage plant, which appeared in the January, 1943, issue of WATER WORKS AND SEWERAGE, have been adapted to forms for a small water plant, and appeared in the November, 1943, issue of WATER WORKS AND SEWERAGE.

TO: DIVISION OF SANITARY ENGINEERING, STATE DEPARTMENT OF PUBLIC HEALTH, SPRINGFIELD, ILLINOIS.

BACTERIOLOGICAL REPORT ON WATER SUPPLY OF _____ FOR MONTH OF _____ 194____

DAY	BACTERIA per ml. (Agar at 37° C.): Raw 50	Appl. 51	Filt. 53	Finished 53	Tap 54	COLI-AEROGENES: RAW (24 hr. Presump. or conf.): 10 ml. 55	1 ml. 56	0.1 57	0.01 58	0.001 59	FILTERED 10 ml.: Presumptive 24 hrs. 61	Presumptive 48 hrs. 62	Part Conf. 63	PLANT—FINISHED 50 ml.: Presumptive 24 hrs. 64	Presumptive 48 hrs. 65	Conf. 66	PLANT—FINISHED 10 ml.: Presumptive 24 hrs. 67	Presumptive 48 hrs. 68	Conf. 69	DISTRIBUTION—SYSTEM 50 ml.: Presumptive 24 hrs. 70	Presumptive 48 hrs. 71	Conf. 72	DISTRIBUTION—SYSTEM 10 ml.: Presumptive 24 hrs. 73	Presumptive 48 hrs. 74	Conf. 75
1																										
2																										
3																										
30																										
31																										
BACTERIA AVE.																										
MAX.																										
MIN.																										

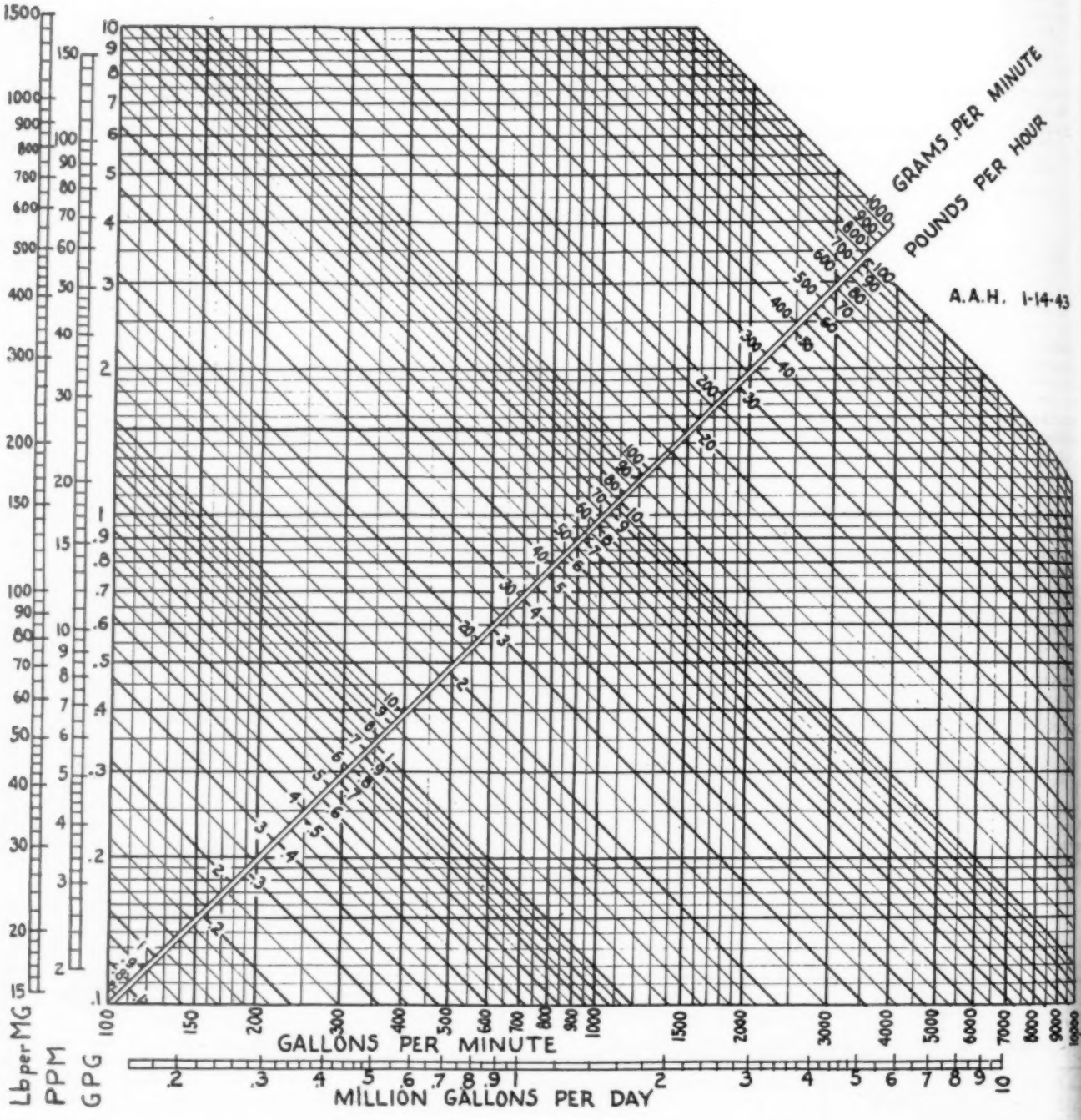
FOR ADDITIONAL REMARKS USE REVERSE SIDE _____

REPORT BY _____ (TITLE) _____

Fig. 3. Form of the Illinois Dept. of Health for Recording and Reporting Bacteriological Results. (Other Illinois forms are similar to those of New York and Ohio.)

CHECKING CHART FOR DRY CHEMICAL FEEDERS

By A. A. HIRSCH*
State Department of Education
Baton Rouge, Louisiana



The chart shown herewith offers a convenient means to check on the delivery of dry feed machines when the pumpage rate and the desired dosage is known. Rate of feed is expressed in grams per minute to enable weighing a timed discharge to check the feeder setting, and in pounds per hour to figure quickly the quantity needed in the hopper for each expected hour of operation. Chlorine dosage may be read knowing the change in platform scale readings per hour and the flow.

Parallel scales along each axis allow rapid conversion from one system of expression to another. On the vertical axis grains per gallon, parts per million and pounds per million gallons are quickly related by scanning directly across the scales. Gallons per minute and million gallons per day are similarly converted along the horizontal scale. In the plot grams per minute and pounds per hour are interchangeable across the diagonal scales. Pounds per hour is more logical from an operator's viewpoint than pounds per day. Many small plants operate only part of a day, or have a limited number of pumping steps, in which case pounds per day is merely a bookkeeping quantity.

A wide range in coverage is provided by the logarithmic divisions. High values not included on the chart may be read by using a tenth or hundredth of the quantity and applying the corresponding multiplier to the reading.

Example. How many grams per minute must be discharged from a dry feeder to give a 2 grain per gallon dosage while operating a 300 gallon per minute system?

Solution. Find the point where the 2 grain per gallon line and the 300 gallon per minute vertical intersect. This point lies between the 35 and 40 gram per minute diagonals at about 38 grams per minute. By projecting this value across the diagonal scales the hourly chemical consumption of 5.0 pounds is read.

When the answer falls in the area occupied by pounds per hour diagonals readings are converted to grams per minute by projecting in the same manner across the oblique scale.

When a metric scale is unavailable grams per minute may be obtained directly by catching the dry feeder discharge for 170 seconds and multiplying the weight in ounces by 10.

*Director, Sectional School on Water Supply and Sewerage.

EXAMINING 100 ML. PORTIONS OF WATER

A Simplified Method Involving Inexpensive Equipment

By H. W. POSTON

Asst. Water Works Supt., Ottumwa, Ia.

THERE has been much comment on the planting of 100 ml. portions in bacteriological examinations of water samples.

At Ottumwa we have developed and used for over one year a procedure which may be of interest to readers of *Water Works & Sewerage*. The procedure has proved quite satisfactory and saved much time as well as given what we believe to be a more complete knowledge of the quality of the water.

One hundred ml. portions are planted only on water leaving the plant. Confirmations on presumptive tubes are made with brilliant green bile. Five one-hundred ml. portions are collected each day, one being taken every two hours during the day.

The procedure of sampling and preparation of the samples before incubation is shown in the photographic series accompanying this article.

Procedure

1. A sterile 8-oz. bottle with inverted fermentation tube (prewar aluminum caps are used to eliminate corrosion during sterilization).
2. Collection of 100-ml. portion in the sterile bottle (bottle has 100-ml. and 135-ml. marks).
3. Sterile *quadruple strength* broth and 100 ml. sample.
4. Adding 35 to 40 ml. quadruple strength broth.
5. Inverting to fill fermentation tube.
6. Sample ready for incubation.

The above procedure eliminates the need for (a) transfer of the 100 ml. portion from a sample bottle to the fermentation vessel; (b) sterile pipettes; (c) sterile sample bottles, and (d) dechlorination of sample—the latter being accomplished with the culture broth.

Sampling and Enrichment of 100 ml. Portions of Water

From left to right, top and then bottom strip, the six steps are described under "Procedure." Note the 100 ml. mark and the 135 ml. mark on the sampling and incubation bottle. No measuring cylinders or pipettes are used in measuring the sample or adding the broth.

IONIC EQUILIBRIUM IN WATER

By H. M. GIFFT
Assoc. Prof. San. Engr., Cornell University, Ithaca, N. Y.

VARIOUS investigators have called attention to the fact that the method for calculating the three forms of alkalinity according to "standard methods" is incorrect. De Martini[1] presented equations for calculating free carbon dioxide and hydroxide, carbonate and bicarbonate alkalinities in terms of total alkalinity and pH. Moore[2] converted these equations to ppm. of free CO_2 and of equivalent $CaCO_3$ and presented them as four graphs. Dye[3] constructed four nomographic charts, and the 1942 Public Health Service Standards included a triangular coordinate diagram, both based on Moore's equations. As pointed out by Moore[2], the graphs were applicable at 25° C., pH values below 10.0, and total solids content less than 500 ppm. Above these values direct solution of the equations* was suggested.

Inasmuch as most waters have pH values of less than 8, the (OH^-) and $(CO_3^=)$ contents are insignificant and, to all practical purposes, the (HCO_3^-) content is equal to the total alkalinity. It is only for waters of high pH, and often of high alkalinities and total solids content, that determinations of (OH^-) and $(CO_3^=)$ are of importance. Therefore, these methods which are applicable only within certain ranges are of limited use.

New Equations

It is possible, however, to evolve three equations which are more easily solved than are those of Moore[2]. Further, by a proper construction of scales, these equations can be combined into one simple chart which yields results directly and without interpolation for any alkalinity content or pH.

From familiar equilibrium equations we have

$$\frac{[H^+] \times [CO_3^=]}{[HCO_3^-]} = K_2' \quad \text{.....Eq. (1)}$$

and $[OH^-] \times [H^+] = K'_w$ .....Eq. (2)

or $\log (OH^-) = pH - pK'_w + 4.70$ .....Eq. (2a)

from which we obtain

$$\frac{[OH^-] \times [HCO_3^-]}{[CO_3^=]} = \frac{K'_w}{K_2'} \quad \text{.....Eq. (3)}$$

or $$\frac{(OH^-) \times (HCO_3^-)}{(CO_3^=)} = 2.5 \times 10^4 \frac{K'_w}{K'_2} \quad \text{.....Eq. (3a)}$$

where (OH^-), (HCO_3^-), and $(CO_3^=)$ represent concentrations in terms of ppm. as $CaCO_3$.

Also

$(OH^-) + (CO_3^=) + (HCO_3^-) =$ Total alkalinity .....Eq. (4)

The three forms of alkalinities may be determined by first solving Eq. (2a) for (OH^-) and then solving Eq. (3a) and (4) simultaneously for $(CO_3^=)$ and (HCO_3^-). Tables I, II, and III include the most recent data on equilibrium constants as reviewed by Larson and Buswell[4].

Simple Nomograph

The exact numerical solution of these equations is rather cumbersome and beyond the accuracy ordinarily required. For these reasons the construction of a simple chart applicable to waters ordinarily encountered has been undertaken. In designing the chart the following simplifying assumptions seemed justified.

As most laboratories are equipped to make pH measurements at 25° C. or room temperature only, the temperature effect might logically be eliminated. On the other hand, as the value of K'_w and K_2' are influenced by the solids content of the water, a correction for this variation was considered necessary.

According to Larson and Buswell K'_w/K'_2 varies 26 per cent between 0 and 1000 ppm. which is equivalent to a pH variation of ± 0.06 or a temperature variation of ± 2.5° C. (The constants used by Moore vary only ± 0.02 and ± 0.6° C., respectively.) K'_w varies 27 per cent over the same range which is also equivalent to a pH variation of ± 0.06 or ± 1.8° C.

Because of these small variations and because of the inaccuracies inherent in the pH and alkalinity measurements and in the determination of the equilibrium constants themselves, the empirical assumption that the total solids content is twice the total alkalinity was considered satisfactory for the construction of the alinement chart in Fig. 1.

According to MacInnes and Belchar[5] K'_1 varies only approximately 1 per cent up to 1000 ppm. total solids. Therefore, using $K'_1 = 4.54 \times 10^{-7}$ at 25° C. and converting to ppm., equation (7) becomes

ppm. $CO_2 = 1.94 \times 10^6 \times [H^+] \times (H\,CO_3^-)$ .....Eq. (8)

The free CO_2 scale in Fig. 1 was constructed from this equation.

Knowing the total alkalinity and pH of a solution (at 25° C.) it is a relatively simple matter to determine the three forms of alkalinity and free CO_2 by means of the alinement chart. The

TABLE I

pK'_w and $K'_w \times 10^{14}$ for Different Temperatures and Total Solids Content (from Larson and Buswell)[4]

Total solids—ppm.	pK'_w / $K'_w \times 10^{14}$	Temperature—°C									
		0	10	20	25	30	40	50	60	70*	80*
0		14.94	14.53	14.17	14.00	13.84	13.53	13.26	13.02	12.81	12.63
		0.12	0.30	0.68	1.008	1.46	2.92	5.47	9.64	15.50	23.50
200		14.88	14.47	14.11	13.94	13.78	13.47	13.20	12.96	12.75	12.57
		0.13	0.34	0.78	1.15	1.66	3.39	6.32	10.96	17.80	26.90
400		14.85	14.44	14.08	13.91	13.75	13.41	13.17	12.93	12.72	12.54
		0.14	0.36	0.83	1.23	1.78	3.63	6.76	11.75	19.1	28.8
600		14.83	14.42	14.06	13.89	13.73	13.42	13.15	12.91	12.70	12.52
		0.15	0.38	0.87	1.29	1.86	3.80	7.09	12.30	20.0	30.2
800		14.82	14.41	14.05	13.88	13.72	13.41	13.14	12.90	12.69	12.51
		0.15	0.39	0.89	1.32	1.91	3.89	7.25	12.60	20.4	30.9

*Values for 70° and 80° extrapolated.

*$(CO_3^=)$ as ppm. $CaCO_3 = \frac{5.61 \times 10^{-8}}{[H^+]} \times \left(\frac{\frac{Alk}{50000} + [H^+] - \frac{10^{-14}}{[H^+]}}{1 + \frac{11.22 \times 10^{-11}}{[H^+]}} \right)$

(HCO_3^-) as ppm. $CaCO_3 = 50000 \left(\frac{\frac{Alk}{50000} + [H^+] - \frac{10^{-14}}{[H^+]}}{1 + \frac{11.22 \times 10^{-11}}{[H^+]}} \right)$

(OH^-) as ppm. $CaCO_3 = \frac{5 \times 10^{-10}}{[H^+]}$

CO_2 as ppm. $= 9.70 \times 10^{10} \times [H^+] \left(\frac{\frac{Alk}{50000} + [H^+] - \frac{10^{-14}}{[H^+]}}{1 + \frac{11.22 \times 10^{-11}}{[H^+]}} \right)$

TABLE II

pK'_2 and $K'_2 \times 10^{11}$ for Different Temperatures and Total Solids Content (from Larson and Buswell)[4]

Total solids—ppm.	pK'_2 / $K'_2 \times 10^{11}$	Temperature—°C									
		0	10	20	25	30	40	50	60*	70*	80*
0		10.63	10.49	10.38	10.33	10.29	10.22	10.17	10.14	10.13	10.12
		2.36	3.24	4.20	4.69	5.13	6.03	6.73	7.20	7.51	7.55
200		10.50	10.36	10.25	10.20	10.16	10.09	10.04	10.01	10.00	9.99
		3.16	4.36	5.62	6.30	6.91	8.12	9.11	9.75	10.00	10.23
400		10.46	10.32	10.21	10.16	10.12	10.05	10.00	9.97	9.96	9.95
		3.46	4.78	6.16	6.90	7.59	8.90	10.00	10.70	10.95	11.22
600		10.43	10.29	10.18	10.13	10.09	10.02	9.97	9.94	9.93	9.92
		3.72	5.12	6.60	7.40	8.12	9.55	10.70	11.47	11.75	12.02
800		10.40	10.26	10.15	10.10	10.06	9.99	9.94	9.91	9.90	9.89
		3.98	5.50	7.08	7.90	8.70	10.23	11.47	12.30	12.58	12.88

*Values for 60°, 70° and 80° extrapolated by Larson and Buswell.

value of (OH^-) is obtained directly from the observed pH. The values for $(CO_3^=)$ and (HCO_3^-) are obtained by pivoting a straight edge until $(CO_3^=) + (HCO_3^-) =$ Total Alkalinity $- (OH^-)$. Both the necessary mental arithmetic and the location of the proper line are easily accomplished.

Example

Two examples of the use of the chart follow:

I. Analysis: Alkalinity 100 ppm. as $CaCO_3$. pH = 10.0.

Solution: pH of 10.0 corresponds to 5.5 ppm. on the (OH^-) scale. Pivoting a straight edge about this point until $(H\ CO_3^-) + (CO_3^=)$ equals $100 - 5.5 = 94.5$, we find $(CO_3^=) = 52$ ppm. and $(HCO_3^-) = 42.5$ ppm. Of course, the CO_2 content is insignificant in this pH range.

II. Analysis: Alkalinity 180 ppm. as $CaCO_3$. pH = 6.9.

Solution: It is easily seen that both (OH^-) and $(CO_3^=)$ values are not significant, thus making the (HCO_3^-) content practically equal to the total alkalinity. A straight edge lined between $(H\ CO_3^-) = 180$ and pH = 6.9 indicates free $CO_2 = 42$ ppm.

Calcium Carbonate Saturation

Langelier[6] made use of these fundamental equations, along with the solubility product for $CaCO_3$, to derive an equation expressing the theoretical pH of a water at $CaCO_3$ saturation in terms of the total alkalinity and actual calcium content. He emphasized the fact that the "Standard Methods" procedure for determining the amount of (OH^-) and $(H\ CO_3^=)$ was in error under certain conditions. In all probability it was for this reason that the final equation was expressed in such a complicated form.* Larson and Buswell[4] proposed a variation of this equation which included correction factors for solids and temperature. The equation was limited to waters of pH below 10.0.

With satisfactory methods for the determination of the (HCO_3^-) alkalinity, it is possible to derive a simple expression for the pH at $CaCO_3$ saturation which is applicable throughout the pH range. By using the corrected values for the equilibrium constants for different temperatures and solids content, the method is further simplified. Combining the equilibrium equations

$$[Ca^{++}] \times [CO_3^=] = K'_s \quad \text{.....Eq. (9)}$$

$$\text{and } \frac{[H^+] \times [CO_3^=]}{[HCO_3^-]} = K'_2 \quad \text{.....Eq. (2)}$$

$$\text{we obtain } [H^+] = \frac{K'_2}{K'_s} \times [Ca^{++}] \times [H\ CO_3^-] \quad \text{.....Eq. (10)}$$

$$\text{or } pH_s = pK'_2 - pK'_s + pCa + p(H\ CO_3^-) + 9.30 \quad \text{.....Eq. (10a)}$$

This equation is similar to the equation $pH_s = pK'_2 - pK'_s + pCa + p\ Alk.$ as given by Langelier[6] for pH_s below 9.5. Hoover's[7] chart apparently was based on this approximate equation since he also limited its use to waters of pH less than 9.5. If the determination of bicarbonate alkalinity is used instead of total alkalinity, Hoover's chart should not be limited to this range.

Although the theoretical pH_s is an indication of the direction for adjustment of pH, it has no direct significance in itself. It is the Saturation Index, or pH — pH_s, which provides the measure of the stability of the water. With a satisfactory determination of $(CO_3^=)$ alkalinity, the calculations of this Saturation Index I, is even further simplified. It can be seen from equation (9) that for stability there is a definite relationship between the (Ca^{++}) and $(CO_3^=)$ contents of a water.

In other words, too great a concentration of either of these ions would indicate a tendency for the precipitation of $CaCO_3$. On the other hand, a deficiency of either of these ions would indicate an excess of carbonic acid. For the water to become stable in a cast iron water main the Fe from the pipe would have to replace the hydrogen in the carbonic acid in order to release the required amount of $(CO_3^=)$ for equilibrium.

Equation (9) may be written as

$$\frac{(Ca^{++}) \times (CO_3^=)}{4 \times 10^9 \times K'_s} = \text{Equilibrium Ratio} \quad \text{.....Eq. (11)}$$

* $$pH_s = pK'_2 - pK'_s + pCa + p\left(Alk. + [H^+] - \frac{K_w}{[H^+]}\right) + \log\left(1 + \frac{2K'_2}{[H_s]}\right)$$

TABLE III

pK'_s and $K'_s \times 10^9$ for Different Temperatures and Total Solids Content (from Larson and Buswell)[4]

Total solids—ppm.	pK'_s / $K'_s \times 10^9$	Temperature—°C									
		0	10	20	25	30	40*	50*	60*	70*	80*
0		8.02	8.15	8.28	8.34	8.39	8.51	8.62	8.74	8.86	8.97
		9.50	7.07	5.25	4.57	4.03	3.06	2.37	1.83	1.38	1.06
200		7.80	7.93	8.06	8.12	8.17	8.29	8.40	8.52	8.64	8.75
		15.85	11.75	8.70	7.56	6.75	5.13	3.98	3.02	2.29	1.78
400		7.73	7.86	7.99	8.05	8.10	8.22	8.33	8.45	8.57	8.68
		18.62	13.8	10.25	8.90	7.95	6.02	4.68	3.54	2.69	2.09
600		7.69	7.82	7.95	8.01	8.06	8.18	8.29	8.41	8.53	8.64
		20.4	15.15	11.2	9.75	8.70	6.60	5.12	3.89	2.95	2.29
800		7.66	7.79	7.92	7.98	8.03	8.15	8.26	8.38	8.50	8.61
		21.9	16.2	12.0	10.45	9.32	7.08	5.50	4.17	3.16	2.46

*Values for 40° and above extrapolated by Larson and Buswell.

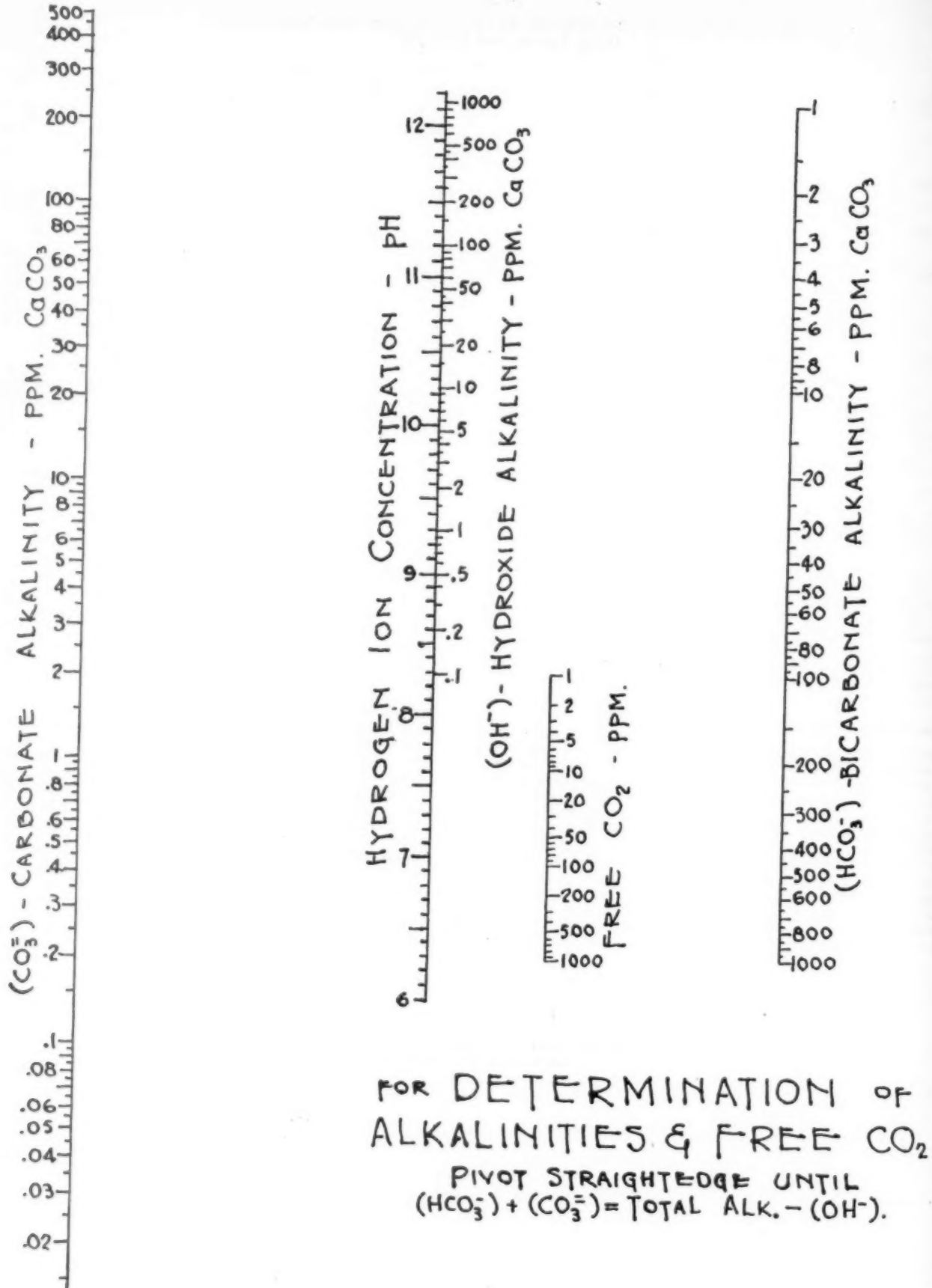


Fig. 1—Nomograph for the Determination of Alkalinities and Free CO_2.

or as

$$\frac{(Ca^{++}) \times (CO_3^{=})}{30.24} = \text{Equilibrium Ratio (at 25°C)} \quad \text{Eq. (11a)}$$

(Ca^{++}) and $(CO_3^{=})$ represent actual concentration in terms of calcium and $CaCO_3$ respectively. A ratio greater than one would indicate scale formation and a ratio less than one would indicate a corrosive water.

To conform to Langelier's Index equation (11) may also be written as

$$I = pK'_s - 9.60 + \log (Ca^{++}) + \log (CO_3^{=}) \quad \text{Eq. (11b)}$$

where a positive I indicates scale formation and a negative value for I indicates corrosiveness.

Summary

Simplified formulas have been presented for the calculation of free CO_2, carbonate, bicarbonate and hydroxide alkalinities from total alkalinity and pH measurements. The method is not limited to any range of alkalinities, total solids content, pH or temperature. A single alinement chart is presented which allows the determination of the three forms of alkalinity at 25° C. without the cumbersome solution of the simultaneous equations. Simplifications have also been made in the $CaCO_3$ equilibrium concept by considering the direct relationship between the actual calcium and carbonate alkalinity concentrations. Application of the necessary corrections for solids content and temperature to the equilibrium constants rather than to the Saturation Index results in a simplified and more convenient expression for the latter.

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KEEPING FILTERS CLEAN WITH CHLORINE

By H. W. POSTON

Asst. Supt., Dept. of Water and Electricity
Ottumwa, Iowa

THERE has been considerable writing about mud-balls, filter cracks, and incrustation of sand in rapid gravity sand filters. Surface wash and high rate wash have been developed. Chemical means for cleaning filter sand include acid, alkali or sulphur dioxide treatment. These methods have all been used for the purpose of keeping foreign material from accumulating on the sand grains and remaining in the filters.

The Ottumwa water supply, taken from the Des Moines River, is treated with chlorine, lime, soda ash, iron sulphate, and carbon dioxide prior to filtration. The settled water going to the filters has a turbidity of between 2 and 10 ppm., most of which is due to the precipitation of calcium carbonate in connection with the softening process. The alkalinity of the applied water is between 30 and 60 ppm., with 10 to 30 ppm. being in the normal carbonate form. During the past two years the pH of the filtered water has been maintained near pH 9.0.

An effective, simple and inexpensive procedure for elimination of foreign material from the filters by means of chlorine application has been developed at the Ottumwa Water Works. A strong solution of chlorine is applied regularly at times when the filters are washed. It is allowed to remain in the filter for a period of approximately twelve hours. (Plant is operated twelve hours per day.) The chlorine solution, when allowed to remain in the filter, dissolves deposits on the sand, kills any bacteria in the filter, and in general keeps the filter free from foreign material which might cause cracks and mud-balls.

This system for keeping the filters clean has been used for the past six to seven years. No trouble has been experienced with mud-balls, filter cracks, or incrustation of the filter sand during this time. The ease of application of this treatment and its economy not only in operation, but also installation, make it a most excellent method for keeping filters clean.

Procedure

For application of chlorine to the filters, which is done each time the filters are washed, the raw water chlorinator is used. Being situated near the wash water pump, no long solution lines are necessary. The only equipment needed was a length of chlorine solution hose, corporation cock, and a chlorine solution tube.

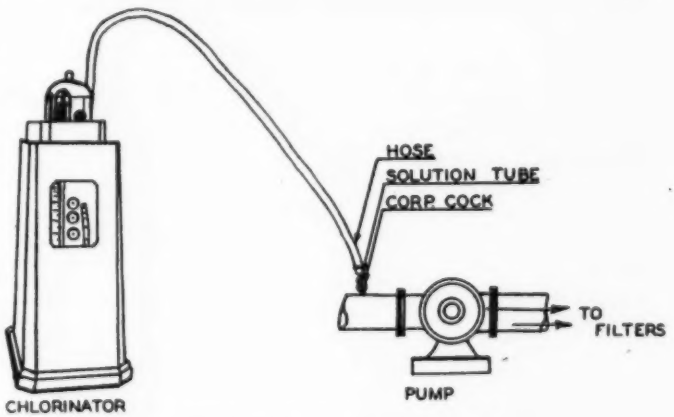
A tap was made in the suction pipe to the wash water pump. The solution tube along with the corporation cock was installed, and connection was made from the chlorinator to the corporation cock with the chlorine solution hose. In operation the set-up is as shown in the accompanying sketch.

Our chlorinator has a capacity of 2,100 lbs. per day. In chlorination of the filter it is set to deliver at the rate of 1,100 lbs. per 24 hours, which will feed about 17 ppm. at maximum wash water rate. The gradual reduction of wash water at the end of the washing period allows the chlorine concentration to be increased to any residual desired.

During an average filter wash, the chlorine residuals of the wash water are as follows: At start, 27 ppm., wash at maximum, 17 ppm., and at end of wash, 40 ppm. The residual on top of the filters is 19 ppm. at the end of the washing period. After standing over night the filters will still carry a chlorine residual of 13 ppm.

Results

Our filters have been in operation since 1933. The sand has never been removed and there is no sign of mud-balls, lime incrustation, or filter cracks.



Chlorinator Hook-up to Filter Wash Line

During the past year our filters were washed after 108 hours' operation on the average. Each filter is washed between ten and twelve minutes. The filter breaks uniformly over the whole bed at the start of the back wash.

There is no evidence to show that the strong chlorine solution has caused any deterioration of pump, pipe line, or filter under drains. The best reason we have for believing the chlorine has had no deleterious effect is its long period of use with no outward sign of damage resulting. At Ottumwa, however, we have no brass in our under drain system which consists of concrete slab false bottoms fed through drilled 8 in. C. I. pipes beneath the distribution slabs.

PITTSBURGH PLATE GLASS COMPANY

COLUMBIA CHEMICAL DIVISION

GRANT BUILDING • PITTSBURGH 19, PA.

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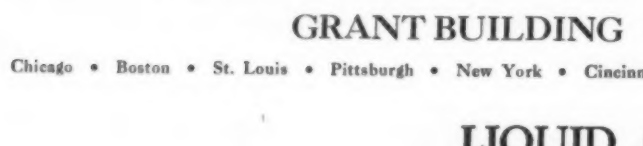
LIQUID CHLORINE



Shipping Units:

30-ton single unit cars
16-ton single unit cars
15-ton multiple unit cars
150 lb. and 100 lb. cylinders

Manufactured in modern plants and shipped in containers which provide every safeguard, Columbia Liquid Chlorine meets the exacting needs of its users.

All containers conform to Interstate Commerce Commission standards and the recommendations of The Chlorine Institute. Columbia cylinders incorporate the latest improvements in design and construction and afford substantial savings in shipping weights. The 100 lb. cylinders are seventeen pounds and the 150 lb. cylinders twenty-nine pounds lighter, respectively, than commonly used types.

Containers are subject to rigid inspection and are at all times maintained in first class condition.

LIGHT SODA ASH

Shipping Units:

Bulk and 100 lb. Paper Bags

Tests 99-100% actual Sodium Carbonate (Na_2CO_3), equivalent to 58% plus Na_2O. One of the original Columbia products, Columbia Soda Ash has remarkable free-flowing properties, rapid solubility, and is noted for the absence of impurities. It is, therefore, highly desirable for use in water treatment.

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SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*
Columbia Alkali Corporation, Philadelphia, Pa.

THERE appeared in the September, 1935, issue of the Journal of the American Water Works Association a valuable report, dealing with chlorine, by the Committee on Chemical Hazards in Water Works. This paper is intended to record various practical experiences in chlorine handling and opinions that in their nature had no place in the above committee report. However, the writer will quote freely from the report, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable nor explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory material to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

Soft copper tubing connections (cadium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "hold" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

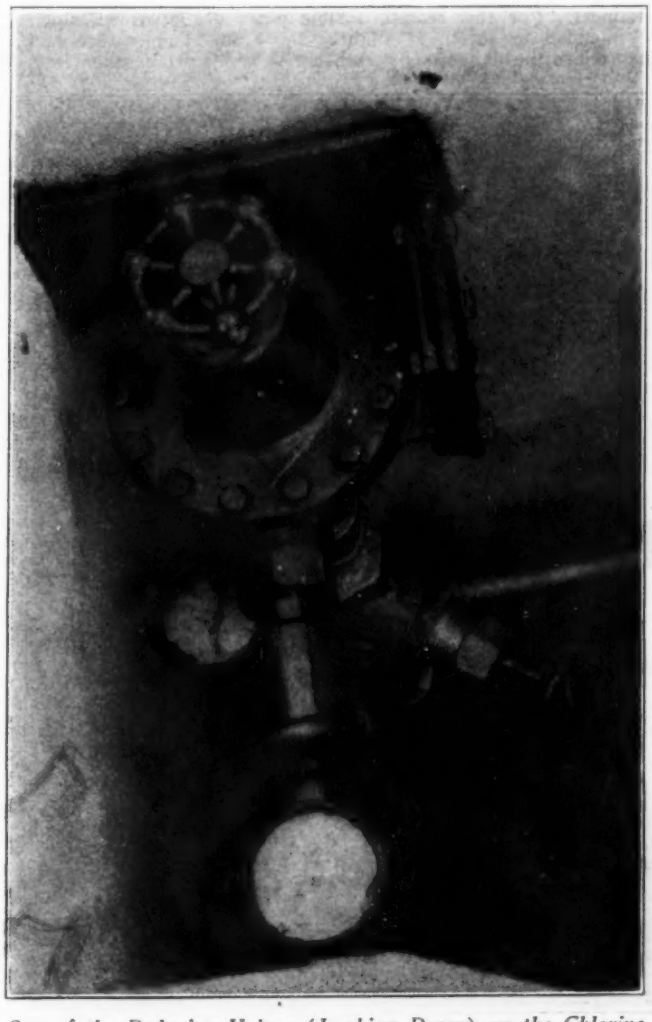
Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va., at time of preparation of this article.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (reliquefaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip-legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-



One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

tetrachloride are the only safe chlorine equipment cleansers to employ.

Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid only the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

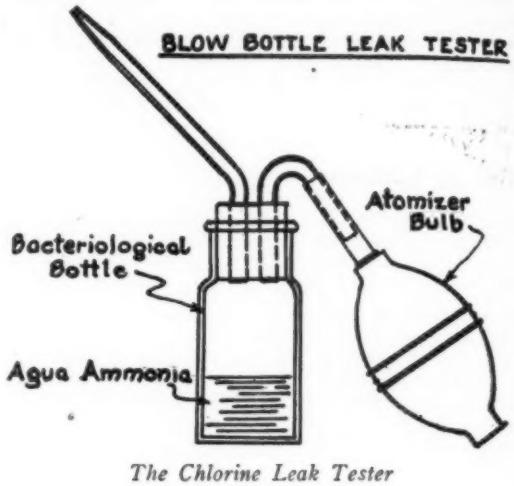
Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overload cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.

Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)



The Chlorine Leak Tester

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed cylinder. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in

use only a few 150 pounds cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus **six machines** give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

SOLVING CHLORINE ICE TROUBLE

By DON CALDERWOOD

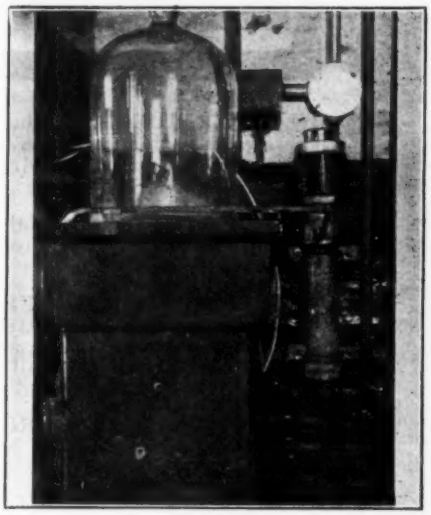
Engineer, Pennichuck Water Works Co.
Nashua, N. H.

IF you have had trouble with chlorine hydrate—usually called chlorine ice—forming in your chlorinator, you may be interested in hearing how we solved this problem.

A few years ago we purchased a Wallace & Tiernan type MCVM chlorinator. The following winter we experienced our first real trouble with so-called chlorine ice. We built a wooden box over the bell jar and put electric lights in it; we tried a unit from a sun bowl heater inside the standard under the tray; and then a combination of both. These gave results after a fashion but did not do a real workmanlike job—so after three or four seasons of makeshift operation we set out to find a permanent solution to the problem.

We purchased a 1,500 watt immersion heater with a three heat switch giving us 500, 1,000, or 1,500 watts as needed. We then took a piece of 2½ inch pipe about 10 inches long, screwed a cap on one end, a reducing coupling on the other, and into the reducing coupling we screwed the 1,500 watt heater. We next tapped into the cap and coupling for ⅛ inch copper tubing and after fastening the assembled unit to the chlorinator we disconnected the water supply line to the tray and with copper tubing made new connections so that all the water going into the tray first passed through the heating unit. To eliminate the possibility of forgetting to turn the heat either on or off, we purchased a pressure switch and connected it to the water supply line in such a way that it automatically turns the current for the heating unit on when we turn on the water supply to the chlorinator, and also turns it off when the water pressure is shut off.

This scheme worked perfectly for about three winters and then a ground started to show on our switchboard. We traced it to the heater and found that in our zeal for efficiency and in our desire to utilize all the heat available we installed the heater with the electric connections pointing down. During the humid summer weather condensation from the outside of the pipe had run down on the electric connections finally causing the ground. We have now reversed the unit, putting the heater in from the top and expect no more trouble. We find that low heat, or 500 watts, is all the current we need to use except for a few days during the coldest part of the winter.



Our First Heater

This heating unit worked so well that we decided to put one on the chlorinator in our other station even though we use that station very little in the cold weather. This chlorinator was an older model and did not have a separate valve and line for the tray water supply, so we connected the heater similar to the other installation but conveyed the warm weather from the heater directly over the top and into the tray. The water supply was adjusted so that the water flowing through the heater and into the tray was just a little less than the required amount, the remainder being supplied in the usual way through the float valve in the tray supply line.

Save With

Ferri-Floc
FERRIC SULPHATE

FERRI-FLOC is the ferric coagulant that is today solving water and sewage problems throughout the United States. In actual plant operations **FERRI-FLOC** is proving most satisfactory for use under widely varying conditions.

In water treatment, the use of **FERRI-FLOC** varies from simple coagulation at normal pH's to softening at high pH's, and color removal at very low pH's.

In sewage plants, **FERRI-FLOC** is being used at high pH values for treatment of concentrated laundry wastes, at extremely low pH values for slaughter house wastes, and at practically all intermediate pH's for treatment of domestic sewage, milk wastes, canning plant wastes, acid wastes, and a multitude of others.

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The Mark of Quality
TENNESSEE CORPORATION

Take advantage of modern plant research and findings: let FERRI-FLOC solve your water or sewage treatment difficulties. Ask Tennessee Corporation's Technical Staff to help you solve your specific problems, or write for case histories of plants with problems similar to yours.

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WATER PURIFICATION

The treatment of public water supplies for sanitary purposes is a highly complex process requiring the services not only of sanitary engineers but also of chemists and bacteriologists. Certain fundamental procedures have become more or less standard, and while not all of these methods of treatment are used at every plant processing water for public use, every plant uses one or a combination of several of the steps outlined here to produce a safe, potable, non-corrosive and soft water.

Water as found in the natural state in lakes, rivers and other surface sources or underground in wells contains dissolved and suspended material in varying quantities.

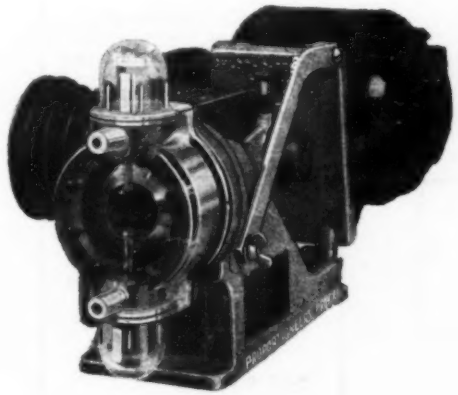

Fig. 1.

HEAVY DUTY MIDGET CHEM-O-FEEDER

Diaphragm pump for all water treating chemicals 0-6.5 GPH against pressure up to 85 PSI. Constant rate feed; adjustable stroke length and rate.

The suspended material can be removed sometimes by simply allowing the water to stand for a sufficient time in a settling or sedimentation tank or basin. As an aid to settling it is necessary with many waters to add chemicals which will coagulate the suspended material and cause it to drop to the bottom of the coagulation basin in a relatively short time.

Aluminum sulphate (filter alum) is one of the chemicals used most frequently for coagulation. It forms a gelatinous precipitate around the suspended particles in the water and causes the particles to adhere to each other forming larger particles which settle more rapidly due to their greater weight. This gelatinous material is known as floc and chemical feed must be regulated so that formation of a suitably sized and constituted floc for rapid settling and good coagulation is obtained. Thus %Proportioneers% accurate chemical feeders for coagulation are designed so that the rate of feed can be adjusted according to changes in the quality of the water being treated. Changes in the natural alkalinity of the water, changes due to seasons of the year, etc., all affect the coagulant demand of the water, so that "flexible" chemical feeding apparatus such as manufactured by %Proportioneers, Inc.% is a necessity.

The next step in the process of water purification is to strain out the smaller particles of floc and suspended matter which were not taken out in the settling chambers or in the coagulation basin. This is done by passing the water through a bed of sand or other porous material. For large quantities of water, such as handled in municipal water treating systems, sand is most generally used for the filtration process. Sand filters will remove not only the suspended matter but also the colloidal material including some of the bacteria and organic matter that cause colored water. The material taken out by the filter may be even smaller than can be seen in a mocriscope,—smaller than the passages through the sand grains. This is possible due to the adsorbing power of the mat of floc or gelatinous material on top of the filter bed, deposited

by the water which was previously treated with coagulants. Sand filters operated at the proper rates of flow, and with correct pretreatment of the water to be filtered, will produce a satisfactory municipal water supply from the standpoint of suspended matter or turbidity, and in most instances color. They will also remove much of the bacterial and organic matter, thus reducing the quantity of chlorine required for sterilization.

There are several types of sand filters in use in municipal treatment plants, including:

1. THE SLOW SAND FILTER:

This filter is built like a reservoir with a layer of sand and, under that, gravel beneath which is a drain system. The filter operates on a gravity flow, removing most of the turbidity and bacteria and much of the coloring matter as the water passes slowly through the sand bed (.05 gal./min./sq. ft.). No coagulant chemicals are used with slow sand filtration.

2. THE RAPID SAND FILTER:

This filter is smaller in area, usually in a concrete basin, and operates at much higher rates of flow (2 gal./min./sq. ft.). It depends on proper sedimentation and coagulation with alum or other coagulants for proper operation. Here, again, water passes through the filter by force of gravity.

3. PRESSURE FILTER:

This filter is a rapid sand filter enclosed in a steel shell and operates under water pressure. Water from a pump discharge or water fom a municipal supply line under pressure, either unfiltered or filtered and requiring further refinement, can be passed through this enclosed filter. Ordinary sedimentation and coagulation can be used, or the coagulant can be injected directly into a pipe line under pressure ahead of the pressure filter.

Cleaning slow sand gravity filters consists of periodically scraping some of the sand from the top surface of the filter. Rapid sand filters of both the gravity and pressure types are cleaned by washing, or "backwashing", as it is referred to sometimes. Filtered water is passed through the filter in reverse flow from bottom to top, thus cleaning the grains of sand and flushing out the top mat of floc and organic matter that has caught the dirt and bacteria. Gravity type rapid sand filters allow the operator to observe the surface of the sand and determine if even backwash is taking place, while pressure filters, being enclosed, do not. However, both these rapid sand type filters can perform a good filtering job when properly operated.

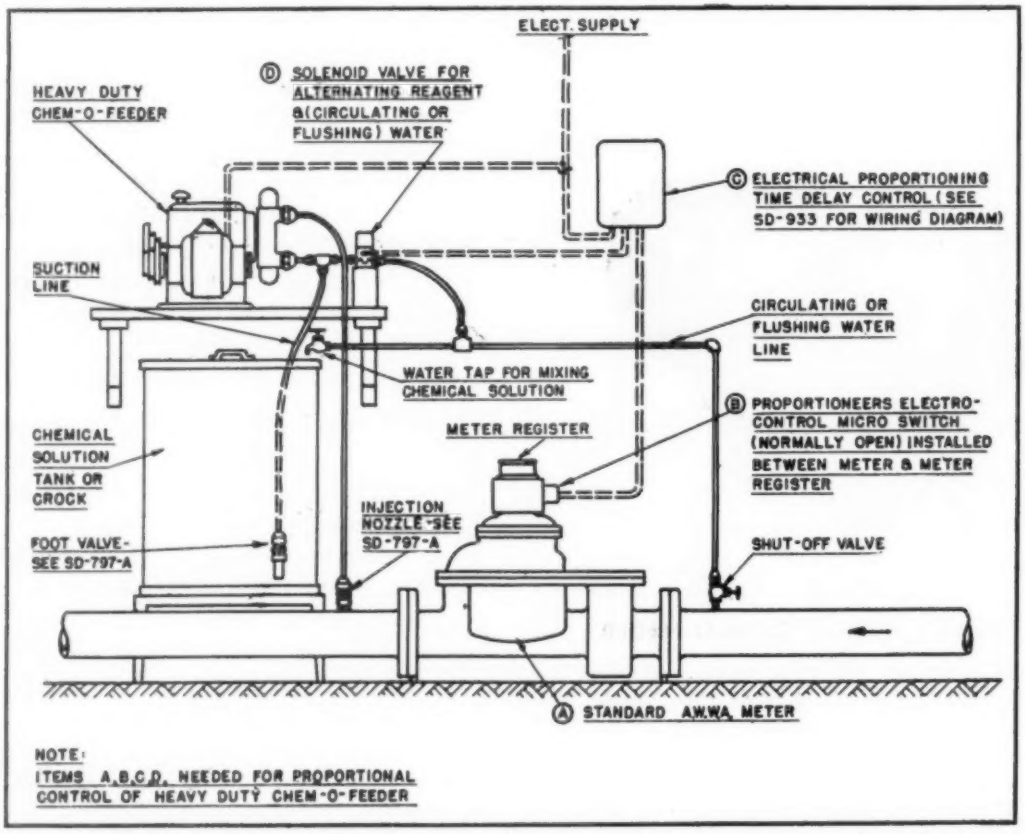
ELECT. SUPPLY
Ⓓ SOLENOID VALVE FOR ALTERNATING REAGENT & (CIRCULATING OR FLUSHING) WATER
HEAVY DUTY CHEM-O-FEEDER
Ⓒ ELECTRICAL PROPORTIONING TIME DELAY CONTROL (SEE SD-933 FOR WIRING DIAGRAM)
SUCTION LINE
CIRCULATING OR FLUSHING WATER LINE
WATER TAP FOR MIXING CHEMICAL SOLUTION
METER REGISTER
Ⓑ PROPORTIONEERS ELECTRO-CONTROL MICRO SWITCH (NORMALLY OPEN) INSTALLED BETWEEN METER & METER REGISTER
CHEMICAL SOLUTION TANK OR CROCK
INJECTION NOZZLE-SEE SD-797-A
FOOT VALVE-SEE SD-797-A
SHUT-OFF VALVE
Ⓐ STANDARD AWWA METER
NOTE:
ITEMS A,B,C,D, NEEDED FOR PROPORTIONAL CONTROL OF HEAVY DUTY CHEM-O-FEEDER

Fig. 2. INSTALLATION DIAGRAM of Heavy Duty Chem-O-Feeder with electrical proportioning device controlled by flow meter.

After filtration the water must be sterilized to provide protection against bacteria that may have passed through the filters and against after-contamination in the distribution system. Chlorine in the form of hypochlorites or as gas chlorine is the most generally accepted and used agent of disinfection. The larger municipal water plants use gas chlorinators and the medium and smaller size plants hypochlorinators. This is because of the differential in first cost of the two types of chlorinators, and the differential in the cost of chlorine in the two forms.

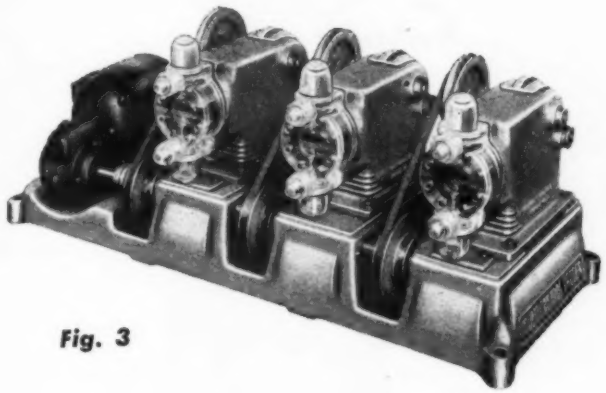

Fig. 3

TRIPLEX MULTI-CONTROL FEEDER

Diaphragm pump for all water treating chemicals 0-7.5 GPH of 3 different chemicals against pressure up to 100 PSI.

Constant rate feed; individually adjustable stroke length and rate for all three chemicals.

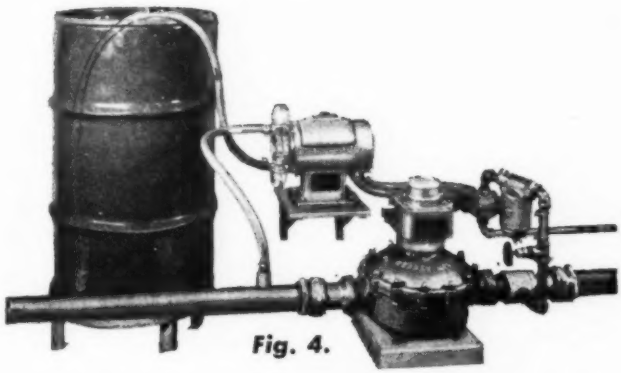

Fig. 4.

AUTOMATIC AND PROPORTIONAL CHEM-O-FEEDER

For all water treating chemicals against 10 to 100 PSI. Automatic and proportional feed to variable flow measured by mechanical meter. Adjustable stroke length.

Chlorine in water oxidizes or burns up the organic matter and bacteria to make it sterile and potable for human consumption. The balance of the chlorine remaining in the water after the organic matter and bacteria have been acted upon is known as the residual chlorine. The chlorine used up is known as the chlorine demand of the water. The chlorine demand of a filtered water will vary from .2 to .6 PPM and it is usual to carry a chlorine residual of .1 to .3 PPM over and above the chlorine demand unless special circumstances dictate otherwise.

The residual chlorine is determined by means of a chlorine comparator in which color standards for known strength of chlorine residuals are used to compare with sample of chlorinated water, to which has been added a small amount of indicator. The indicator (orthotolidine solution) reacts with the residual chlorine and causes a color to appear in the sample corresponding to the amount of residual chlorine.

Chlorination before filtration or pre-chlorination is used in some plants to control the load of organic matter and bacteria on the filters. Chlorination after filtration or post-chlorination is used where disinfection only is required.

Ammonia, as the gas or in the form of aqua ammonia or ammonium sulphate, is used for treating some waters together with chlorine. Chloramines formed when both ammonia and chlorine are added to a water have two distinct advantages:

1. Enables carrying higher residuals which will persist and carry further out in the distribution system without resulting chlorinous taste and odor.
2. With some waters taste and odor can be controlled with chloramine treatment.

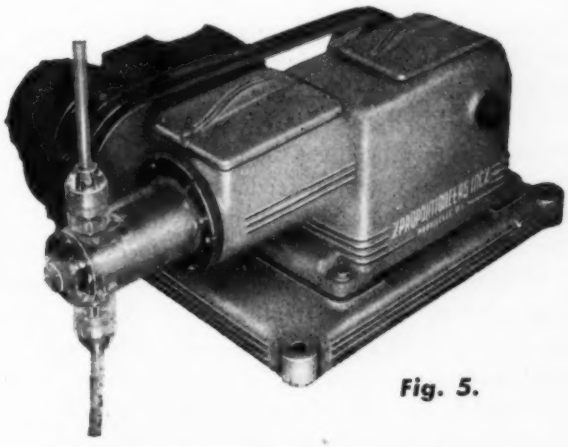

Fig. 5.

HIGH PRESSURE MIDGET CHEM-O-FEEDER

Plunger pump for all water treating chemicals 0-6.5 GPH against 30 to 200 PSI.

Constant rate feed; adjustable stroke length.

Save With Ferri-Floc

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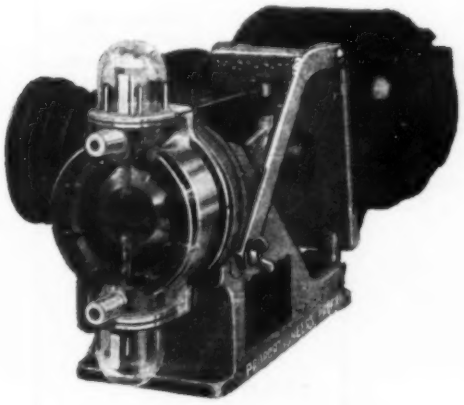

Fig. 1.

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Ammonia and chlorine react together to form mono, di and tri-chloramines. The mono and di-chloramines are the sterilizing agents and appear to be more selective in their action than chlorine alone. Also, higher residuals can be carried without taste and odor problems that would arise if chlorine alone was used. Thus, instead of being used up entirely by organic matter in the water at or near the treating plant, they tend to react more exclusively on the bacteria. The higher initial residual is carried in the mains to act on pollution out in the ends of the distribution system which would not be reached with chlorine alone. There is some evidence that higher chlorine residual reacts to prevent bacterial growths and organic matter in the mains from cutting down their carrying capacity. With some waters containing phenolic wastes, chlorine forms offensive tastes and odors. If ammonia is added before the chlorine, it reacts with the phenolic matter, thus preventing chlorophenolic tastes and odors. The ammonia is added before or after filtration, depending entirely on where the chlorine is added when the problem is taste and odor control. Chloramines do not help where tastes and odors are already present in the water before the chlorine is added.

Other miscellaneous treatments applied to particular water supplies include softening by the lime-soda ash or zeolite methods, iron and manganese removal, corrosion control with silicates or phosphates, aeration and lime treatment, etc. The special purpose treatments are required for various reasons, but not usually for improving suitability of the water for sanitary purposes.

%Proportioneers% has over the past ten years developed a complete line of chemical feeders for adding or injecting under pressure the various chemicals used in the aforementioned purification and treatment processes. These Chem-O-Feeders are variable displacement pumps for feeding solutions of the treatment chemicals. %Proportioneers% chemical food pumps take solution from a chemical tank, measure it and deliver it to the desired point of application. Diaphragm pumps are used to feed to low or negative pressures, such as a pump suction, into atmospheric pressures, such as an open tank, or into positive pressures, such as a water main, up to 85 or 100 lbs. per square inch depending on the model Chem-O-Feeder used. Plunger pumps, for positive pressures from 30 lbs. per square inch up to 200 lbs. per square inch or higher, are available.

Pumped, or constant rate of flow, water systems are usually treated with electric motor-driven Chem-O-Feeders, adjustable as to stroke length, stroking rate and solution strength. Chem-O-Feeders are available, however, for belt or chain and sprocket drive from some rotating shaft on your equipment. Other models can be driven from a reciprocating motion on your equipment, such as a steam-driven reciprocating pump.

For variable rate of flow water plants, such as a gravity water system, %Proportioneers% has a complete line of hydraulically operated mechanical meter-controlled proportioning pumps. Other equipment for electric motor drive, but controlled by a mechanical water meter electrically, is also available.

Fig. 6.

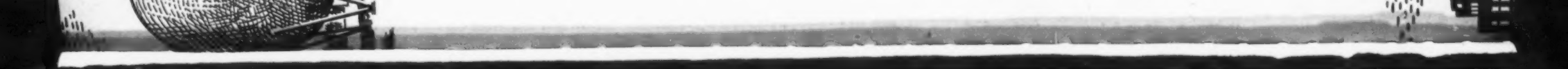
PACKAGED AMM-O-FEEDER

Diaphragm pump for aqua ammonia solution 0-6.5 GPH aqua ammonia up to 15% against pressure to 85 PSI. Suitable for water plants up to 25 MGD. Constant rate feed; adjustable stroke length and rate.

Pressure differential meters, such as the Venturi, orifice plate, etc., can be used to control %Proportioneers% Chem-O-Feeders by use of the Chronoflo Transmitter manufactured by our associate company, Builders-Providence, Inc.

Behind %Proportioneers% water treating equipment stands a company which for over a decade has pioneered better proportioning pumps in countless fields. The experience gained in over 17,000 installations—treating water supplies, blending and diluting ingredients for vital war products, sampling the flow of liquids—qualifies %Proportioneers, Inc.% to solve your problem, to engineer more reliable, economical and accurate water treating equipment for present and future plants.

Technical data, recommendations and bulletins on specific chemical feeders will be sent you upon receipt of information about your chemical treatment problem.



PART 7

SEWAGE TREATMENT

WATER WORKS
& SEWERAGE

REFERENCE & DATA SECTION

1945

OLIVER UNITED FILTERS INC.

New York 18, N. Y. 33 W. 42nd Street | Chicago 1, Ill. 221 N. La Salle Street | Western Sales Div., Oakland 1, Calif., 2900 Glascock Street | San Francisco 11 California | E. Long, Ltd. Orillia, Ontario

Factories: Oakland, Calif. — Hazleton, Pa. — Orillia, Ont., Canada — Melbourne, Australia

PRODUCTS

Oliver Continuous Vacuum Sludge Dewaterer.
Olivite Acid-Handling Pump (Centrifugal Pump for Handling Chemicals).
OD5 Diaphragm Slurry Pump.

EXPERIENCE

Oliver United engineers pioneered the development of continuous vacuum dewatering for the various types of sludges produced in treatment plants. They cooperated with consulting engineers and sewage plant officials in working out coagulation methods to make these sludges amenable to mechanical dewatering.

ADVANTAGES OF CONTINUOUS VACUUM DEWATERING

The benefits of mechanical sludge dewatering are such that *every* community, wherever practical, should plan to adopt this method of handling sludges.
Briefly, here they are:

1...space required for the filter station is very much less than that required for equivalent capacity in drying beds.

2...the filter operates continuously, regardless of weather conditions.

3...sludge is handled more easily and at any convenient time.

4...nuisance factors are eliminated.

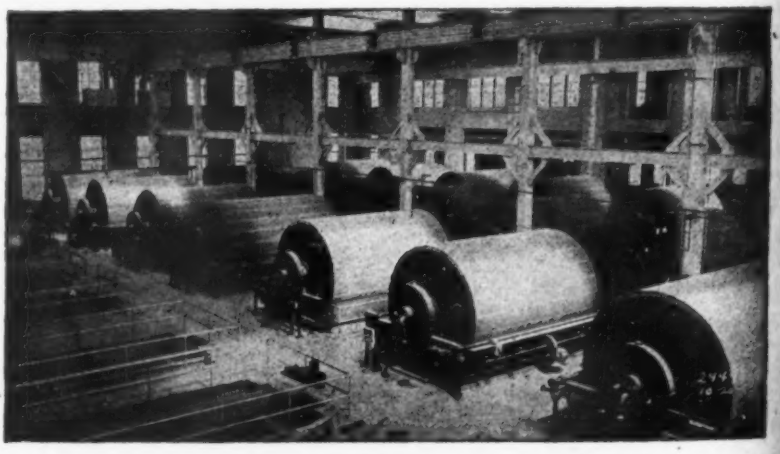
5...filter station easily kept clean.

6...filter and accessories have exceptionally long life; some Olivers have been in service continuously for 21 years.

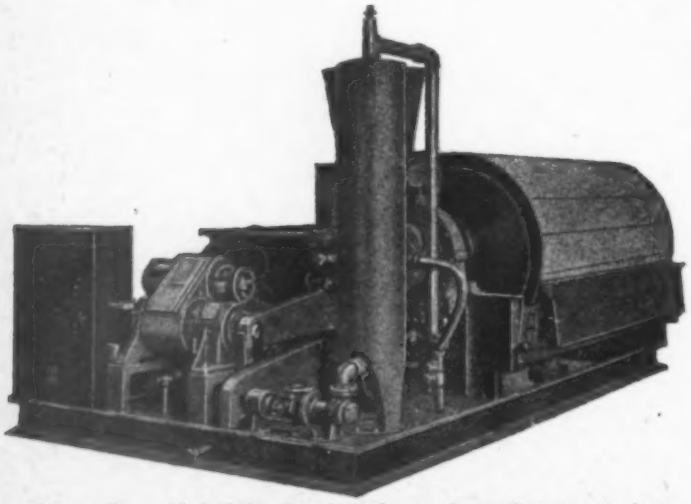
OLIVER UNITED INSTALLATIONS

Since 1924, when the first Oliver Continuous Vacuum Sludge Dewaterer was installed, Oliver United engineers have engineered and manufactured about 125 continuous vacuum dewaterers. Sizes installed range from 54 square feet to 800 square feet. Two different stations—Milwaukee and Chicago (Stickney)—have 24 and 32 large Olivers respectively.

55,000 square feet of
OLIVER UNITED
SEWAGE SLUDGE DEWATERERS
have been installed in
Sewage Treating Plants



Part of installation of thirty-two 11' 6" x 16' Olivers at Chicago (Stickney Plant)



Oliver all-assembled Sludge Dewaterer for use in small treatment plants

SLUDGES HANDLED

Continuous vacuum dewatering is practicable for handling the following sludges:

Raw Waste Activated
Raw Primary
Digested Primary
Digested Mixed Raw and Activated
Chemically Precipitated
Water Softening
Water Softening and Sewage
Tannery Waste and Sewage
Many Industrial Wastes

MODERN FINANCING OF SEWAGE WORKS*

FINANCING sewage works by revenue bonds secured by service charges is comparatively new. It is, however, a form of financing which promises wide acceptance because it is equitable and economically sound. Here are reasons why:

Sewer rental charges are small:

When billed on a monthly or quarterly basis, charges are accepted without question after the first few billings;

Delinquencies are, for the most part, negligible;

Purchasers of revenue bonds have good security.

In this booklet revenue bonds are considered as a form of municipal bond issued to construct or improve revenue-producing works when the payment of such bonds depends entirely upon the revenue from the utilities. These include sewerage systems, sewage-disposal and water works.

Although the full faith and credit of the political subdivision is not directly pledged as security for revenue bonds, the financial standing and debt history of a municipality have an important bearing upon the value of the bonds. Revenue bonds should be considered as a sound means whereby progressive municipalities may build needed improvements without disrupting other budgeted requirements and without adding anything to their general debt or tax burdens.

State and Municipal Legislation

Legislation permitting revenue bond financing of sewage works exists in 33 states. Because some of these laws were passed as emergency measures, amendments may be necessary to make the full benefits available. If enabling legislation is not adequate or is of temporary nature, it should be amended. An enabling act should provide that the department of the municipality responsible for building and operating public works may proceed with a required sewerage project upon the approval of the common council or board of trustees, and after a satisfactory ordinance has been drawn. [If the reader is interested in a typical Revenue Bond Ordinance a copy will be supplied upon request. The length of the ordinance was too great for reproduction here.—

In some cities home rule charters may have to be revised to permit taking advantage of the broader scope of state legislation.

It is important that any change in state legislation or in municipal charters be suggested only after careful study of the state constitution and existing laws.

Kinds of Financing

The problem of financing sewerage facilities is of major importance to municipalities. Although most of the discussion in this booklet concerns the revenue bond method, other means are touched upon, since some cities may find them desirable. There are four principal methods for financing sewerage facilities:

1. General Tax Obligation Bonds;
2. Special Assessments;
3. Service Charge and Revenue Bonds;
4. Combination Method.

General Tax Obligation Bonds

The most used method of financing municipal improvements has been by ad valorem tax upon all real property within the municipality. Bonds have then been issued upon the basis that the improvement becomes a general obligation of the incorporated municipality. This method considers the improvement of general benefit to all property, and the tax paid by an owner to be in direct proportion to the amount of property he possesses without recognizing the utility feature of water works and sewerage.

In times of stress this method may not permit the city or town to construct or extend sewerage facilities that are vitally needed. When an improvement is most needed, the municipality may have a bonded indebtedness approximating the state constitutional or statutory limitation.

Special Assessments

The special assessment method of financing is based upon the taxing of property in proportion to the benefits bestowed. The property owner may pay his share of the cost of the undertaking outright or in a stated number of installments, usually ten. When an installment is due he receives a notice. He is expected to pay promptly what is due plus interest on the unpaid balance.

Special assessment bonds may or may not be issued, depending upon the municipality's ability to carry the cost out of other funds, or the willingness of the contractor to take assessment warrants in at least part payment.

This method of financing also leaves out of consideration payment in proportion to service rendered.

Service Charge Revenue Bonds

The revenue bond method of financing public improvements does not add to the general debt. Sewer rentals which are security for the bonds provide a means of charging the person receiving the service and in proportion to use.

The most practical method of sewer rental is a charge based on water consumption. A sewer rental schedule may be set up by ordinance for various classes of users, and users may be charged a fixed percentage of the water bill.

If for any reason it is not practicable to use water meter readings, rates can easily be adjusted to a flat rate or connection basis, depending upon the kind and size of premises occupied and the number of service connections. In any case, individual demands should be carefully studied and classified and the rates fixed accordingly. [A typical rate ordinance is given at the end of this chapter.—Editor.]

The monthly or quarterly per capita charge for the entire cost of a new sewage works plus its operating cost is generally quite small, and therefore no hardship even on the very low income group. The minimum rate at Oak Park, Illinois, for example, is $1.50 per quarter, or less than the cost of a daily paper. Of the 11,500 accounts on Oak Park's books, approximately 2,600 pay the minimum bill, and 3,600 pay the next higher rate.

Combination Financing

Sewer rentals may be charged even though the project may not be financed with revenue bonds. In some cases sewer service charges have been used merely to care for maintenance and operation. The equity of charging the user a proportion of the construction cost, however, is well recognized.

Also, sewer rentals may be used to retire general tax obligation bonds used for sewer construction. Furthermore, in ordinances establishing sewer rentals for operation and maintenance, it is usually provided that any surplus accruing from the rental collections shall be applied to the construction cost.

Where extensions or construction of waterworks are being considered with sewerage improvements, it is often advantageous to finance with combined waterworks and sewerage revenue bonds.

Sewer Rental Experience

Some fear has been expressed regarding possible delinquencies in sewer rental collections. Those who anticipate this difficulty will find that their fears have little foundation in practice. Examination of the sewer rental experience table reproduced herewith shows the small percentage of delinquencies.

In financing sewage works by the revenue bond method, questions may arise regarding the equity of the rates for sewer rentals. While the rate depends largely upon service actually used, it must be recognized that there is a definite benefit to property whether the sewer is connected or not.

An accepted principle of making a ready-to-serve or availability charge can be applied to the establishment of sewer rental rates. This principle may also be extended to cover the cost of storm sewers or, if a combined system is built, a share of the added cost.

Various methods have been used for establishing such charges. In some cases the sewer rental charge has been made to finance the construction of the treatment plant, and the cost of the collection system has been met by an entirely different method, usually some form of direct taxation or special assessment.

Where sewer rentals are to be applied to construction of both treatment plant and collection system, some municipalities have established a small ready-to-serve charge. Another and fairly general practice is to make a substantial charge for initial connection to the sewer.

(See Experience Record at end of article.)

*The material under this heading has for the most part been taken from a brochure published by the Portland Cement Association, copies of which are available upon request.

General Procedure

Carrying a sewerage project through under any kind of financing involves a number of important steps. These do not necessarily follow in order, and some of them may be taken concurrently. The principal steps are:

Make a preliminary sanitary survey;
Start a campaign to get public support;
Select a competent sanitary engineer;
Select a recognized bond attorney to prepare the bond ordinance and bond certificates;
Publish the bond ordinance;
Advertise the bond issue;
Prepare the rate schedule and publish the rate ordinance;
Prepare forms for billing the user.

Preliminary Survey

Before the need for new sewerage facilities is determined, it is desirable to have some public sentiment favorable to such improvement. The water supply may have become contaminated, and householders will start to complain of disagreeable tastes and odors. Public bathing beaches may have to be closed. Marine life may have been endangered by pollution. State health departments may have determined that a nuisance exists. All these conditions may indicate new sewage works are required, but the actual need should be established by a preliminary survey. Such a survey need not be comprehensive, but enough facts should be gathered to justify the improvement.

Securing Public Approval

Now that the municipality has decided to proceed with the construction of sanitary facilities and it has been determined that there are no legal barriers, the next logical step is to enlist widespread public support. Even though bonds may be issued without referring the matter to popular vote, the public should be informed on the urgency of the proposed construction and the entire plan of procedure.

Many city councils prefer a referendum so that there will be official record of the public's approval.

When, and if, the bond issue is to be put to a vote of the people, it is essential that the voters have full knowledge of the necessity of the project, and that they be given enough construction and operation cost information to impress them with the fact that for an exceedingly small charge they are being given an indispensable service. Many bond issues have been lost because voters gained erroneous impressions from unreliable sources.

Public approval of the proposed project should be sought through a general educational campaign, which should point out:

That public health is endangered by continuation of existing conditions;

That the city may be (or has been) sued because of stream pollution and that the taxpayers will have to pay for the resulting damage;

That sound financing methods will be followed;
That costs will be reasonable;
That engineering advice and construction supervision will be competent;
That charges will be small and on the basis of use;
And further, that there will be no added tax burdens.

The whole educational program should be placed in the hands of a competent central committee. The following outline suggests major steps in an educational campaign:

A. Establish central committee
   1. Headquarters
   2. Volunteers
   3. Appoint publicity director
B. Report on investigations
   1. Engineer's report
   2. Financing methods (advice obtained from bond attorneys)
   3. Comparable conditions in other cities
      How remedied?
C. Publicity
   1. Newspaper articles
      Full details given to press; cooperation obtained in interest of public welfare
   2. Advertisements—if election to be held, present final conclusive arguments immediately preceding election day
   3. Booklets and pamphlets —simple, direct statements
D. Canvassing
   1. Individual calls by volunteers
   2. Endorsements by prominent citizens.
E. Local organizations
   1. Obtain support of local groups
      Business
      Professional
      Chambers of commerce
      Women's organizations
      Civic clubs
      Schools, etc.
F. Lectures and radio talks
   1. By city officials
      Engineers
      Attorneys
      Volunteer citizens
G. Displays
   1. Posters in store windows
   2. Posters in homes

Selecting the Consulting Sanitary Engineer

The job of building modern sewage works requires highly specialized ability, and should be entrusted only to a competent sanitary engineer.

Although the sanitary engineer will know what facts he will have to gather, others not technically trained will be interested in a brief picture of the scope of his necessary investigations, which are as follows:

Source and quality of water supply.

Stream-gage measurements, particularly low-water and flood stages, if the water supply is taken from a river or the sewage effluent is to be diverted to a river or stream.

Population characteristics, with particular reference to population stability, proportions in various income groups, whether population is increasing or decreasing, etc.

Land use characteristics of the area. It should be known what proportion of the area to be served is industrial; how much is commercial and how much residential, with these areas located with respect to municipal corporate limits or sanitary district limits; and the recreational facilities of the community, etc.

Physical characteristics of the area. Obviously, a physical survey will have to be made to determine where the plant is to be built to take full advantage of gravity flow of sewage, to determine if any pumping will be necessary, and to solve other problems concerned with actual design.

The number of water connections in the area to be served by sewerage facilities, and the probabilities of increase. Adequacy of existing water supply and probable reasonable increase also will be established. It should certainly be known how many sewer connections exist and whether the connections are industrial, commercial or residential.

Method of garbage collection and disposal.

These are a few of the many important things the sanitary engineer will investigate.

Selecting Bond Attorney

A recognized bond attorney should be consulted at the outset. In cooperation with the city attorney, the bond specialist will prepare and approve the necessary ordinances and form of bond proposal.

This procedure not only protects the city against legal faults, but it helps materially in selling the bonds. An opinion of a recognized bond attorney will be necessary before the bonds are delivered, but a preliminary opinion is desirable, as it obviates subsequent delay. Also, if bond purchasers know that all details have been handled or approved by bond specialists, the bonds will be regarded much more favorably.

Publishing Bond Ordinance

As soon as the bond attorney and the city attorney have drafted the bond ordinance, the city council should pass the ordinance and publish it. The way is then clear for financing the project.

Advertising Bond Issue

City officials will find helpful suggestions regarding the bond advertisement in a municipal circular issued by the Investment Bankers Association of America. These suggestions, embodied in Recommendation No. 19, are:

"19. SPECIAL REVENUE BONDS:

"Reference is made to a resolution adopted by the Board of Governors on May 11, 1937, that part of which outlining specifications is as follows:

" 'That advertisements or circulars describing revenue bonds shall clearly indicate the nature of the obligation.

" 'That the customary form of the ordinary municipal circular and advertisement be varied to prevent confusion in the mind of the casual or careless reader.

" 'That the type of obligation be clearly described in the caption, and with prominence consistent with that accorded to the name of the municipality.

" 'That priority of obligation, if any, be stated specifically.

" 'That the statement of assessed valuation, total debt, etc.,

if included, be given a secondary rather than a primary position.

"'That in connection with such statement of assessed valuation, etc., a statement shall be made, and prominently displayed, to the effect that the assessed valuation reported is not subject to taxation for the payment of principal and interest on the bonds.'"

Bonds may be offered for sale as soon after the issue has been advertised as seems convenient or advisable. The services of some financial specialist may be secured to advise the city officials when the bonds may be most advantageously sold and in what amounts.

Establishing Rate Schedule

An equitable rate schedule is fundamental to successful financing of sewerage facilities by the revenue bond method. Obviously, then, care must be exercised in adjusting the schedule to the kind and amount of service rendered.

The recommendations of the sanitary engineer should be sought in establishing the rates. He will view the proposed schedule from the standpoint of existing earning capacity plus reasonable future increases. It cannot be emphasized too strongly that an adequate and equitable rate schedule will enhance the possibilities for advantageous sale of the bonds. An inadequate schedule may jeopardize the entire program. Raising deficient rates is far more difficult than lowering rates found to yield more revenue than is currently required.

Preparing Billing Forms

Municipalities have worked out ingenious methods of billing to meet their particular requirements. A simple statement showing separately the amounts charged for water and for sewerage service is generally preferred, however. Where possible, the billing and collection of sewerage charges can be made by the same staff and at the same time as the water bills. This has been done by several cities at almost no increase in collection costs.

It is especially desirable that bills be rendered monthly or quarterly. An annual charge for a new municipal service, however reasonable, may appear exorbitant to the payer.

Two single billing forms are reproduced on the next page.

Typical Sewer Rental Ordinance

AN ORDINANCE

FIXING THE RATES TO BE CHARGED BY THE CITY OF DAYTON, OHIO, TO THE OWNERS OF BENEFITED PROPERTY FOR THE USE OF ITS SANITARY SEWERAGE SYSTEM, OF PARTS SANITARY SEWERAGE SYSTEM AND TREATMENT WORKS.

WHEREAS, . . . THEREFORE,

BE IT ORDAINED BY THE COMMISSION OF THE CITY OF DAYTON:

Section 1. It is hereby determined and declared to be necessary and conducive to the protection of the public health, safety, welfare and convenience of the City of Dayton, Ohio, to levy and collect charges or rentals upon all lots, lands, and premises served by having connections with the sanitary sewerage system and by the sewage pumping, treatment and disposal works of said City, the proceeds of such charges or rentals so derived to be for the use of the sanitary sewerage system and the pumping, treatment and disposal works of said city, as hereinafter provided.

Section 2. (Defines "Sanitary Sewage" and "Industrial Wastes."—Editor).

Section 3. For the purposes as provided in Sections 1 and 8 hereof there is hereby levied and assessed upon each lot, parcel of land, building or premises having any sewer connection with the sanitary sewerage system of said city or otherwise discharging sewage, industrial wastes, water or other liquids, either directly or indirectly into the City sanitary sewerage systems, a sewerage service charge or rental payable as hereinafter provided, and in amount determinable as follows:

(a) For any lot, parcel of land, building or premises situated within the corporate limits of the City of Dayton, Ohio, and having any connection with the city sanitary sewerage system or otherwise discharging sanitary sewage, industrial wastes, water or other liquids, either directly or indirectly, into the City sanitary sewerage system, said charge or rental shall be based upon the quantity of water used thereon or therein as the same is measured by the City water meter there in use, and there shall be charged: for the first 3000 cubic feet of water, or part thereof, so used per quarter year, the sum of One Dollar ($1.00); for each thousand cubic feet of water used in excess of 3000 cubic feet and not exceeding 10,000 cubic feet, per quarter year, at the rate of Thirty Cents (30c) per 1000 cubic feet; for each thousand cubic feet of water in excess of 10,000 cubic feet and not in excess of 20,000 cubic feet, per quarter year, at the rate of Twenty-five Cents (25c) per 1000 cubic feet; for each thousand cubic feet of water in excess of 20,000 cubic feet and not in excess of 100,000 cubic feet per quarter year, at the rate of Twenty Cents (20c) per 1000 cubic feet; for each thousand cubic feet in excess of 100,000 cubic feet and not in excess of 500,000 cubic feet per quarter at the rate of Fifteen Cents (15c) per one thousand cubic feet; for each thousand cubic feet in excess of 500,000 cubic feet per quarter at the rate of ten cents (10c) per 1000 cubic feet; provided, that the minimum charge shall be One Dollar ($1.00) per quarter year or part thereof.

(b) For any lot, parcel of land, building or premises situated outside of the corporate limits of the City of Dayton, Ohio, and having any connection with the city sanitary sewerage system or otherwise discharging sanitary sewage, industrial wastes, water or other liquids, either driectly or indirectly, into the city sanitary sewerage system, said charge shall be based upon the quantity of water used thereon or therein as the same is measured by a water meter there in use which meter shall be to the approval of the Director of Water, and there shall be charged for the first 3000 cubic feet of water, or part thereof, so used per quarter year, the sum of One Dollar and Twenty-five cents ($1.25); for each thousand cubic feet of water used in excess of 3000 cubic feet and not exceeding 10,000 cubic feet, per quarter year, at the rate of Thirty-eight cents (38c) per thousand cubic feet; for each thousand cubic feet of water in excess of 10,000 cubic feet and not exceeding 20,000 cubic feet per quarter year at the rate of Thirty-one cents (31c) per thousand cubic feet; for each thousand cubic feet of water in excess of 20,000 cubic feet and not exceeding 100,000 cubic feet per quarter at the rate of twenty-five cents (25c) per thousand cubic feet; for each thousand cubic feet in excess of 100,000 cubic feet and not in excess of 500,000 cubic feet per quarter, at the rate of nineteen cents (19c) per thousand cubic feet; for each thousand cubic feet in excess of 500,000 cubic feet per quarter at the rate of thirteen cents (13c) per thousand cubic feet; provided that the minimum charge shall be One Dollar and Twenty-five cents ($1.25) per quarter year or part thereof.

(c) In the event a lot, parcel of land, building or premises discharging sanitary sewage, industrial waste, water or other liquids into the City sanitary sewerage system, either directly or indirectly, is not a user of water supplied by the Department of Water of said City and the water used thereon or therein is not measured by a city water meter, or by a meter acceptable to the Director of Water, then, in each such case the amount of water so used shall be otherwise measured or determined by the Director of Water in order to determine the sewer service charge or rental provided in this ordinance, or the owner or other interested party at his expense may install and maintain a meter acceptable to the Director of Water for said purpose.

(d) In case a lot, parcel of land, building or premises discharges industrial wastes, either directly or indirectly, into the City sanitary sewerage system, and the Director of Water finds that it is not practical to attempt to measure such wastes by meter, he shall measure such wastes in such manner and by such method as he may find practicable in the light of the conditions and attendant circumstances of the case, in order to determine the sewer service charge or rental, according to the corresponding rates per thousand cubic feet provided in this ordinance.

(e) A discount of five (5) per cent shall be allowed for prompt payment.

In addition to the charge or rental determined according to the rates specified herein a further charge of five (5) per cent of such amount so determined shall be added thereto in each case of failure to make prompt payment, and the total thus obtained shall be the sewerage service charge or rental in each such case.

("Prompt Payment" defined.—Editor.)

(f) The sewer service charge or rental provided in this ordinance shall be payable quarterly at the office of the Department of Water, and, at the option of the Director of Water may be made payable at the same time as water bills in the district in which the property is located are payable.

(g) (Exempts City, County, State, and Federal property except specified institutions.—Editor.)

Section 4. For any lot, land, building or premises from which connection is made with the City sanitary sewerage system or which begins to discharge sewage, any industrial waste, water or other liquids into the City sanitary sewerage system, either directly or indirectly, after this ordinance becomes effective, a charge shall be made pursuant to this ordinance, the same to be a

per diem pro rata amount based upon the minimum rate per quarter from the time such sewer connection is made, or such discharge into the City sewerage system, either directly or indirectly, is begun, until the next following quarter period, except should the measured service exceed the minimum charge the corresponding measured rate or rates shall be charged.

Section 5. The charge or rental levied and assessed by this ordinance shall be payable in four quarterly payments in each year, as provided in Section 3, paragraph (f), hereof, provided that the amount of the rental payable for any lot or premises at the first payment period after this ordinance becomes effective shall be determined on the basis of a per diem pro ratement or the minimum charge herein established beginning with the date this ordinance becomes effective, except that in those cases in which the metered or measured charge will exceed the minimum charge, the metered or measured charge shall be the basis.

Section 6. Each charge or rental levied by or pursuant to this ordinance is hereby made a lien upon the corresponding lot, land or premises served by a connection to the sanitary sewerage system of the City of Dayton, Ohio, and if the same is not paid within thirty (30) days after it shall be due and payable it shall be certified to the Auditor of Montgomery County, Ohio, who shall place the same on the tax duplicate of said county with the interest and penalties allowed by law and be collected as other taxes are collected.

Section 7. The charges or rentals levied pursuant to this ordinance shall be collected by the Department of Water, and the Director of said Department shall make and enforce such by-laws and regulations as may be deemed necessary for the safe, economical and efficient management and protection of the City sewerage system and the sewage pumping, treatment and disposal works, for the construction and use of house sewers and connections to the sewerage system, and for the regulation, collection, rebating and refunding such charges or rentals.

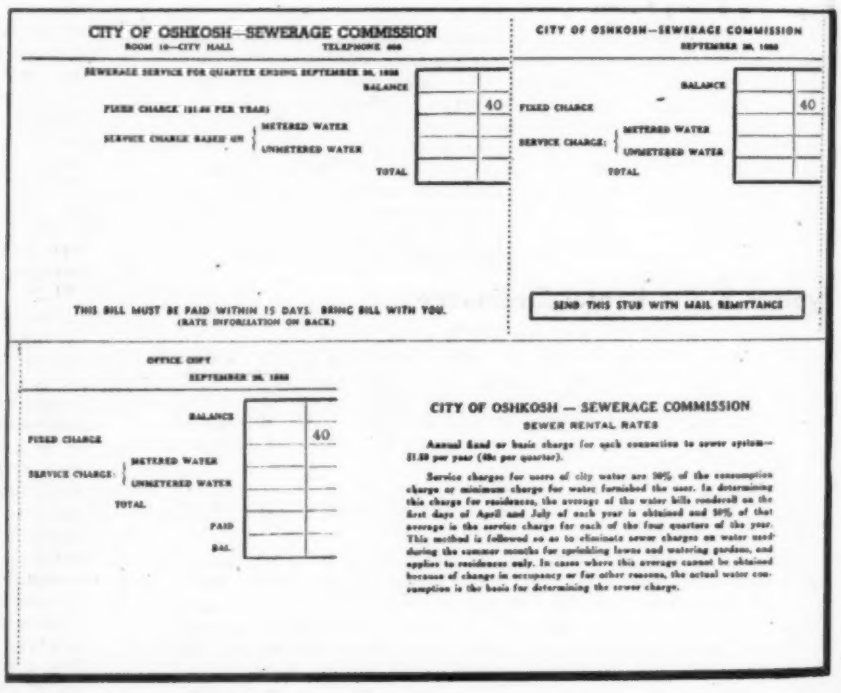
Section 8. The funds received from the collection of the charges or rentals authorized by this ordinance shall be deposited daily with the City Treasury and shall be accounted for and be known as the Sanitary Sewer Fund, and when appropriated by the City Commission, shall be available for the payment of the cost and expense of the management, maintenance and repair of the City sanitary sewerage system and the sewage pumping, treatment and disposal works, and any surplus in such fund shall be used for the payment of the interest on bonds issued and outstanding or which may be issued to provide funds with which to pay the City's portion of the cost of constructing such sanitary sewerage system, or part thereof, and such sewage pumping, treatment and disposal works and to retire such bonds when they mature, and/or for the enlargement or replacement of said sanitary sewerage system, pumping, treatment and disposal works, except that no part thereof shall be used for the extension of such sewerage system into unsewered areas.

Passed by the Commission December 28, 1927.

Typical Billing Forms

The billing side of the Oshkosh, Wisconsin, form at right is in three sections, the sewer rental rates being shown on the reverse side.

The billing form below is used by the City of Lebanon, Illinois



CITY OF OSHKOSH—SEWERAGE COMMISSION
ROOM 10—CITY HALL TELEPHONE 466

SEWERAGE SERVICE FOR QUARTER ENDING SEPTEMBER 30, 1938

BALANCE
FIXED CHARGE ($1.60 PER YEAR) 40
SERVICE CHARGE BASED ON { METERED WATER / UNMETERED WATER
TOTAL

THIS BILL MUST BE PAID WITHIN 15 DAYS. BRING BILL WITH YOU.
(RATE INFORMATION ON BACK)

CITY OF OSHKOSH—SEWERAGE COMMISSION
SEPTEMBER 30, 1938

BALANCE
FIXED CHARGE 40
SERVICE CHARGE: { METERED WATER / UNMETERED WATER
TOTAL

SEND THIS STUB WITH MAIL REMITTANCE

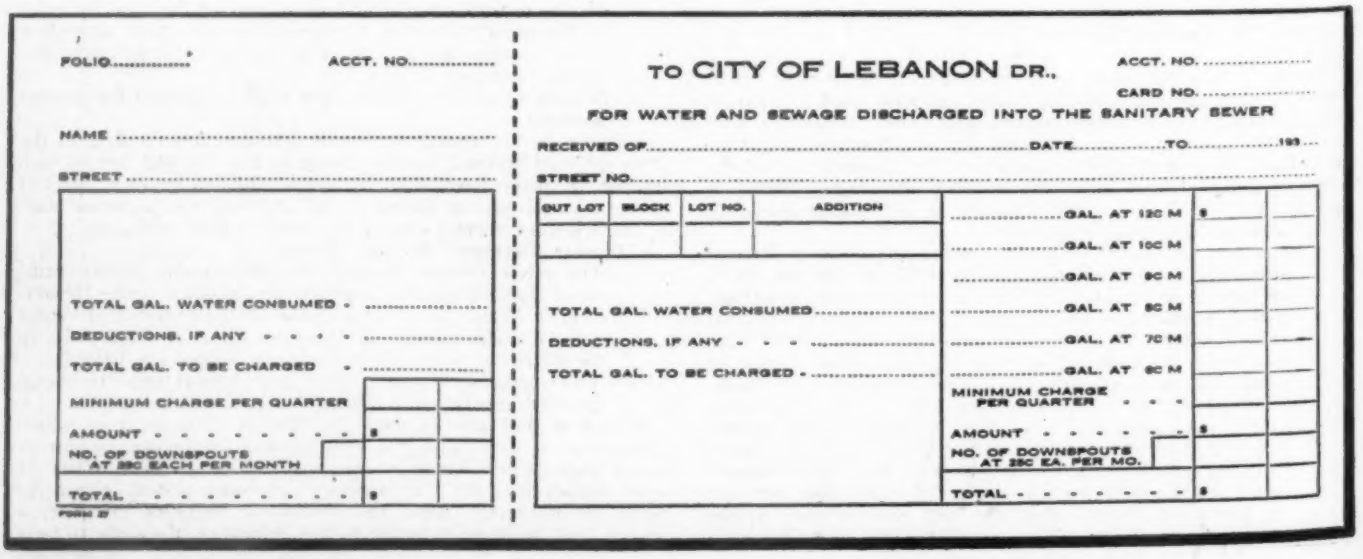
OFFICE COPY
SEPTEMBER 30, 1938

BALANCE
FIXED CHARGE 40
SERVICE CHARGE: { METERED WATER / UNMETERED WATER
TOTAL
PAID
BAL.

CITY OF OSHKOSH — SEWERAGE COMMISSION
SEWER RENTAL RATES

Annual fixed or basic charge for each connection to sewer system—$1.60 per year (40c per quarter).

Service charges for users of city water are 50% of the consumption charge or minimum charge for water furnished the user. In determining this charge for residences, the average of the water bills rendered on the first days of April and July of each year is obtained and 50% of that average is the service charge for each of the four quarters of the year. This method is followed so as to eliminate sewer charges on water used during the summer months for sprinkling lawns and watering gardens, and applies to residences only. In cases where this average cannot be obtained because of change in occupancy or for other reasons, the actual water consumption is the basis for determining the sewer charge.



POLIO..... ACCT. NO.....

NAME .....

STREET .....

TOTAL GAL. WATER CONSUMED - .....
DEDUCTIONS, IF ANY - - - - .....
TOTAL GAL. TO BE CHARGED - .....
MINIMUM CHARGE PER QUARTER
AMOUNT - - - - - - - - $
NO. OF DOWNSPOUTS AT 25C EACH PER MONTH
TOTAL - - - - - - - - $

FORM 27

TO CITY OF LEBANON DR., ACCT. NO. .....
CARD NO. .....

FOR WATER AND SEWAGE DISCHARGED INTO THE SANITARY SEWER

RECEIVED OF..... DATE..... TO..... 19...

STREET NO.....

OUT LOT	BLOCK	LOT NO.	ADDITION

TOTAL GAL. WATER CONSUMED.....
DEDUCTIONS, IF ANY - - - .....
TOTAL GAL. TO BE CHARGED - .....

.....GAL. AT 120 M $
.....GAL. AT 100 M
.....GAL. AT 90 M
.....GAL. AT 80 M
.....GAL. AT 70 M
.....GAL. AT 60 M
MINIMUM CHARGE PER QUARTER - - -
AMOUNT - - - - - - $
NO. OF DOWNSPOUTS AT 25C EA. PER MO.
TOTAL - - - - - - - $

SEWER RENTAL EXPERIENCE

STATE & CITY	POPULATION	FINANCED WITH REVENUE BONDS	RATE BASIS: WATER CONSUMPTION	RATE BASIS: OTHER METHODS	BILLING METHODS: MONTHLY	BILLING METHODS: QUARTERLY	DELINQUENCIES	REMARKS ON COLLECTIONS
ARKANSAS								
Batesville	4,500	Yes		Flat rate	Yes			Citizens protest.
Brinkley	3,048	Yes		Flat rate	Yes			
Fordyce		Yes		Flat rate	Yes			Some difficulty due to protests.
Little Rock	80,000	Yes	Yes		Yes		6 to 8%	Some protest from tenants.
Stuttgart		Yes		No. of connections				
Waldron		Yes		Varies with service				Very little difficulty.
West Memphis	2,900	Yes		No. of fixtures	Yes		Negligible	Few protests.
FLORIDA								
Ft. Lauderdale	(Max.) 40,000	Yes	Yes		Large meters	Small meters	Less than 5%	
Tallahassee	15,000	No		No. of fixtures	Yes		0	A few protests on first bill.
GEORGIA								
Athens	22,000	No		No. of fixtures			5%	
ILLINOIS								
Anna	4,000	Yes		No. of connections		Yes	0	
Barrington	4,000	Yes	Yes			Yes	4½%	Few protests.
Belvidere	8,123	Yes	Yes			Yes	5%	
Edwardsville	6,500	Yes	Yes	Also flat rate	Yes		15%	Object to not having referendum
Effingham	5,301	Yes		No. of connections		Yes	10%	
Elmhurst	15,000	Yes	Com'l.	Flat rate residences	Yes		½%	
Kankakee	22,300	Yes		No. of fixtures	Yes (also bi-monthly)		6%	No unusual difficulties.
Kewanee	17,000	Yes	Yes				12%	No difficulties.
Libertyville	4,000	Yes	Yes			Yes	½%	
Monmouth	9,000	Yes	Yes		Yes		10%	
Rochelle	3,890	Yes	Yes			Yes		No difficulties.
Sullivan	3,300	Yes	Yes		Yes		¼%	No difficulties.
Waterloo	2,300	Yes		Flat rate	Yes		Very small	
West Chicago	3,900	Yes	Water & sewer combined			Yes	5%	
West Dundee	1,800	Yes		Flat rate		Yes	1%	Few mild protests.
INDIANA								
Bloomington	18,227	Yes	Yes (discharges into sewer)		Yes		1%	No difficulty.
Goshen	12,000	Yes	Yes (plus flat rate & connect. chg.)		Yes		10%	No difficulty.
Kokomo	32,843	Yes	Yes	Also flat rate	Yes		7%	Some objections at first—
La Porte	16,000	Yes	Yes	Flat rate	Large users	Small users	10%	none now.
Michigan City	30,000	Yes	Yes	Flat rate	Yes		10%	Very little difficulty.
Mitchell	3,226	Yes	Yes				0	
IOWA								
Cedar Rapids	60,000	Yes	Yes		Yes (also bi-monthly)		Very small	No difficulty.
Ft. Dodge	25,000	No	Yes			Yes		
Iowa City	15,340	Yes	Yes		Yes			Some protests.
Mt. Vernon	1,500	Yes	Yes			Yes		
KENTUCKY								
Beaver Dam	1,050	No		No. of fixtures	Yes		0	
Providence	5,000	Yes	Yes		Yes		8%	Slight difficulty with some.
Richmond	7,500	Partly	Yes	Also flat rate	Metered	Flat rate	0	Some objections to rate.
LOUISIANA								
Jennings	6,500	No		Flat rate on water bill	Yes		2%	
MICHIGAN								
Ann Arbor	30,000	Yes	Yes		Partly	Yes	Less than 1%	No difficulty.
Battle Creek	45,000	Partly	Yes		Yes		4 to 6%	Some complaints.
Grand Haven	8,345	Yes	Yes		Yes		4%	
Jackson	55,000	Yes	Yes (based on winter months)		Yes			No difficulty.
Traverse City	13,000	No	Yes			Yes	8%	Difficulty at first only.
NEBRASKA								
Adams	535	No		Flat rate	Yes			
Blue Hill	669	No		Flat rate	Yes			
Columbus	8,000	Yes		Flat rate		Yes	Less than 1%	
Lawrence	528	No		Flat rate	Yes			
Peru	835	Yes		Flat rate	Yes			
Trenton	865	Yes		Flat rate	Yes			
NEW YORK				Balance charged				
Buffalo	563,000	Yes	Yes (55%)	against real property	Monthly, quarterly & semi-annually			
Plattsburgh	13,347	Yes		Flat rate and no. of connections				
OHIO								
Bedford	7,400	No	Yes			Yes		
Berea	5,687	No	Yes			Yes		
Bowling Green	6,688	No		Flat rate		Yes	Negligible	
Dayton	200,982	Partly	Yes (Modified)			Yes		
Findlay	19,363	Partly	Yes		Yes		6%	No serious difficulty.
Greenville	7,038	Partly	Yes			Yes	None	No difficulty.
Mansfield	33,525	No	Yes			Semi-annually	5%	A few protests at first.
Oxford	2,588	Yes	Yes			Yes		
Springfield	68,763	No	Yes			Semi-annually		
Toledo	290,718	No	Yes			Yes	20% but will be collected: loss not more than .03%	
PENNSYLVANIA								
Abington Township	18,500			No. of fixtures			None	
Cheltenham Township	18,200	No		No. of fixtures		Annually	Small	
Haverford Township	25,000	No		No. of fixtures		Annually	Few	
Jenkintown	5,000					Annually	Small	
Media	5,000	No	Yes	Also no. of connect'ns		Annually	5%	
Radnor Township	12,317			No. of fixtures		Annually	Small	
Springfield Township	5,000			No. of fixtures		Annually	Few	
U. Moreland Township	4,500	Partly				Annually	10%	
TENNESSEE								
Lawrenceburg	3,500	Yes		Flat rate	Yes		None	
Parsons	1,000	Yes		Flat rate	Yes		None	
TEXAS								
Alvin		No		Flat rate	Yes		5%	No difficulties.
Big Spring	15,500	No		Flat rate	Yes			
Brownsville	25,000	No		No. of connections	Yes		1%	Only few protests.
Corpus Christi	56,000	Yes	Yes (with		Yes		3%	Some difficulty because no
El Paso	102,000	Yes	min. charge)	Flat rate			None	deposit required.
Jasper	4,500	No		Flat rate	Yes		5%	
La Feria	1,600	No		No. of connections	Yes		10%	No protests.
Lufkin	10,000	No		No. of fixtures		Yes	None	
Mineral Wells	7,000	No		No. of fixtures	Yes		10%	
Raymondville	3,800	No		Flat rate & fixtures	Yes		30%	Owners and renters disagree on
Snyder	4,000	No		Connections & fixt.	Yes		None	who should pay.
Sweetwater	15,000			Fixtures	Yes		None	
Wharton	3,600		Yes	Minimum & fixtures	Yes		None	
VIRGINIA								
Berryville	1,200	Yes		Flat rate		Semi-annually	10%	
Christiansburg	2,000	No		Flat rate	Yes		4%	
Herndon	1,000	Partly		Flat rate		Yes		
Roanoke San. Dist.	6,000	Yes		Flat rate		Yes	None	
Williamsburg	3,778	No		Flat rate		Yes	4%	
Winchester	12,500	No		Flat rate		Annually	1%	
WISCONSIN								
Oshkosh	40,108	Mostly	Yes	Flat rate		Yes		

(We recommend to the reader the 120-page brochure "Sewer Rentals," recently published by the American Public Works Association, 1113 East 60th St., Chicago.—Cost to non-members, $1.50.—Ed.)

THE AMERICAN BRASS COMPANY

General Offices: WATERBURY 88, CONNECTICUT

ANACONDA
from mine to consumer

Everdur Metal

For Sewage Treatment Equipment, Reservoir and Water Works Service

FOR SEWAGE TREATMENT EQUIPMENT

Air filter of secondary room of the Ward's Island Sewage Disposal Plant. Framework of filter structure and filter holders are welded and bolted Everdur Sheet and Strip. Retaining mesh for filter is perforated Everdur Sheet. Fabricated by American Filter Co., Inc.

Control mechanicism of 12" diameter Everdur float tubes. Designed by Krajewski-Pesant Mfg. Corp. for the Ward's Island Sewage Disposal Plant, New York City.

Everdur* Metal, The American Brass Company's copper-silicon alloy, is offered as one of the most versatile materials available for the fabrication of sewage treatment equipment. It has given superior service in this field for more than eighteen years.

Everdur, made in several types, consists essentially of copper and silicon, with controlled additions of other elements. The tensile strength, in wrought form, ranges from a minimum of 50,000 lbs. per sq. in. for annealed tank plates to approximately 100,000 lbs. per sq. in. in cold worked forms. Everdur alloys all possess high fatigue resistance and resistance to corrosion equal to or better than pure copper. There are Everdur alloys adjusted for hot working and for cold work, and, with two exceptions, these metals are readily welded by either the oxy-acetylene torch or the carbon arc.

Applications

The principal applications of Everdur for sewage treatment are as follows: coarse and fine screens, swing gates, built-up sluice gates, coarse bar rack aprons, effluent weirs and scum weirs, scum baffles and brackets, troughs, screen hoppers, orifices, baskets, anchors, ladders, float gage chain, valve springs, manhole steps, walkways, bars and plates, bolts and nuts, Electrical Metallic Tubing and Rigid Conduit.

Advantages

Because of its high strength, corrosion-resistance and weldability, Everdur has effected considerable economies in equipment previously made of heavy iron castings. Relatively lightweight wrought sheets of Everdur, assembled by welding, provide much lighter, more easily operated, and more durable equipment.

Everdur Metal costs less than most high strength corrosion-resistant alloys, and not only meets many of the definitely determined corrosion problems of sewage treatment, but also provides the necessary additional protection where the forces of corrosion are variable.

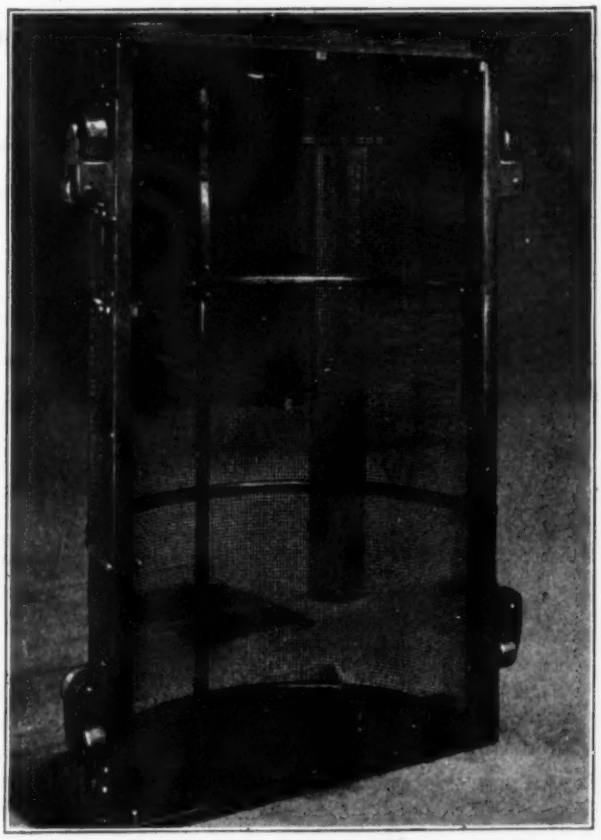
*Everdur is a trade-mark of The American Brass Company. Registered in the U. S. Patent Office.

More than 100 of these Everdur weir plates, 3/16" thick, were installed in the concrete treatment tanks of the Coney Island Sewage Treatment Works. The 3/16" slots are 4" long, milled on ⅜" centers and relieved on the underside. Plates are anchored with 1" x 2½" Everdur bolts.

THE AMERICAN BRASS COMPANY

FOR RESERVOIR AND WATER DISTRIBUTION SYSTEMS

Everdur Metal is performing highly satisfactory service as an engineering material in reservoir and water distribution systems. Convincing evidence of the superiority of Everdur for water handling equipment lies in the fact that it had been adopted before the war by the majority of manufacturers of automatic domestic water heaters as the standard tank material for rust-proof tanks.



Everdur copper-silicon alloy screen frame in the gatehouse of a New England water company.

Applications

Its chief uses may be listed as: screens, screen frames, spillway fittings, flash board supports, bolts, steps, valve stems, flush box fittings and pipe. The largest use of Everdur for underwater equipment has been for concrete revetment installations in Mississippi River flood control projects. Hundreds of thousands of pounds of Everdur in the form of solid wire, stranded wire, clips, saddles, U-bolts and nuts have been used in the making, assembling and laying of the articulated concrete mattresses, which provide the river bank protection.

Advantages

Durable, corrosion-resistant installations in masonry

Fabricating economies because of its weldability with the carbon arc and oxy-acetylene torch

High tensile strength

Engineering Service

Members of the Technical Department of The American Brass Company will be glad to confer with Consulting and Sanitary Engineers regarding specific sewage treatment or reservoir and water works systems. A request for this engineering service entails no obligation.

Publications Furnished on Request

E-11 (Everdur for Sewage Treatment Equipment)
E-5 (Applications, Physical Properties and Constants)
E-6 (Everdur Bolts, Screws and Accessories)
E-1 (Everdur Casting Ingots)
E-13 (Everdur Tanks and Equipment)
B-22 (Anaconda Electrical Conduit)

OFFICES AND AGENCIES

Atlanta 3, Ga.	66 Luckie Street	Newark 2, N. J.	714 Broad Street
Boston 10, Mass.	140 Federal Street	New York 4, N. Y.	25 Broadway
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Chicago 7, Ill.	1326 W. Washington Blvd.	Pittsburgh 12, Pa.	1228 Brighton Road
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Cleveland 14, Ohio	2906 Chester Avenue	Rochester 4, N. Y.	183 Main Street, East
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Milwaukee 7, Wis.	229 East Lincoln Avenue	Waterbury 88, Conn.	414 Meadow Street
Minneapolis 2, Minn.	527 Marquette Avenue		

IN CANADA:

Anaconda American Brass Limited, *General Offices,* New Toronto, Ontario
Montreal Office: 939 Dominion Square Building

MINE SAFETY APPLIANCES CO.

Braddock, Thomas & Meade Streets, Pittsburgh, Pa.

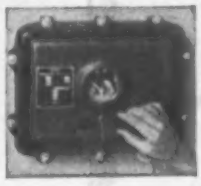
District Representatives in Principal Cities

M.S.A. Products include: Breathing Apparatus . . . Inhalators . . . Approved Dust Respirators . . . Masks of All Types . . . Gas Indicators . . . Gas Detectors . . . Safety Goggles . . . Protective Hats and Caps . . . Edison Electric Cap Lamps . . . Safety Belts . . . Safety Clothing . . . Dust Instruments . . . First Aid Equipment . . . Protective Hand Creams

Descriptive Bulletins will be sent on request.

M.S.A. COMBUSTIBLE GAS ALARM

A development of the M.S.A. Research Laboratories. The Alarm is accurate, highly sensitive; operates any type of electrical warning signal or control and is sensitive to practically any combustible gas or vapor. Designed for permanent installation and continuous operation, the instrument may be set to respond at any point between 10% and 100% of lower explosive limit. The Combustible Gas Alarm is well adapted to detecting leakage of digester gas into boiler rooms, pump rooms, gas meter rooms, pipe galleries, and other enclosures. Uses ordinary 110-volt current.



M.S.A. AMMONIA MASK
Bureau of Mines Approved

The most widely used mask wherever ammonia is employed or generated. All-Vision Facepiece covers entire face, offering complete protection to eyes as well as lungs from the ammonia fumes. Wide-area lenses are equipped with deflector which prevents fogging of eyepieces. Face-piece is connected by flexible tube to highly efficient ammonia - absorbing chemical canister. Entire unit permits complete working freedom and is exceptionally comfortable to wear.

M.S.A. CHLORINE MASK
Bureau of Mines Approved

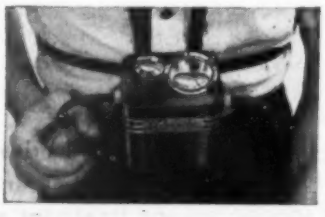
Full protection against chlorine concentrations in air is provided by this canister-type mask. Unit is equipped with All-Vision all-rubber facepiece, which provides unobstructed vision through greatly - enlarged lenses of shatter-proof glass. It adjusts easily and quickly, fits any face without drawing or binding, and permits natural breathing, hearing, sight and working freedom.

M.S.A. HYDROGEN SULPHIDE DETECTOR

A hand-operated instrument for quick detection and measurement of low but dangerous concentrations of hydrogen sulphide in air—the only device of its type available. Provides a reliable method any workman can use to test suspected atmospheres, showing actual gas concentrations at the working place in amounts ranging from .0025% to .40% by volume, thus showing relative toxicity of atmosphere. Small, light, easy to carry and simple to operate, this Detector gives accurate reading in less than a minute.

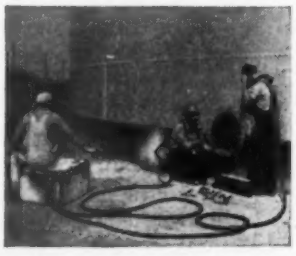
M.S.A. EXPLOSIMETER
Model 2

A sensitive, compact, simplified combustible gas indicator for checking suspected atmospheres on-the-job to determine whether combustible gases or vapors are present. Equipped with carrying straps, the user is free to operate the instrument with one hand and the sampling line and probe tube with the other. Separate battery compartment, one-piece flow system, easy-reading meter, built-in filter chamber, spare filament, and On-Off signal bar to prevent instrument from being left with batteries connected are important Model 2 features.



M.S.A. COMBINATION HOSE MASK

Officially approved by both the U. S. Bureau of Mines and the American Gas Association. An extra-capacity, hand-operated blower furnishes one or two workmen with fresh outside air through as much as 150 feet of hose to each mask, permitting them to enter and work freely in any gaseous or oxygen-deficient atmosphere. Other fresh-air masks are also available in both hand-operated and motor-driven types. The All-Vision Facepiece is standard equipment on all M.S.A. Hose Masks.



DESCRIPTIVE BULLETINS ON ANY OF THE ABOVE EQUIPMENT WILL GLADLY BE SENT ON REQUEST

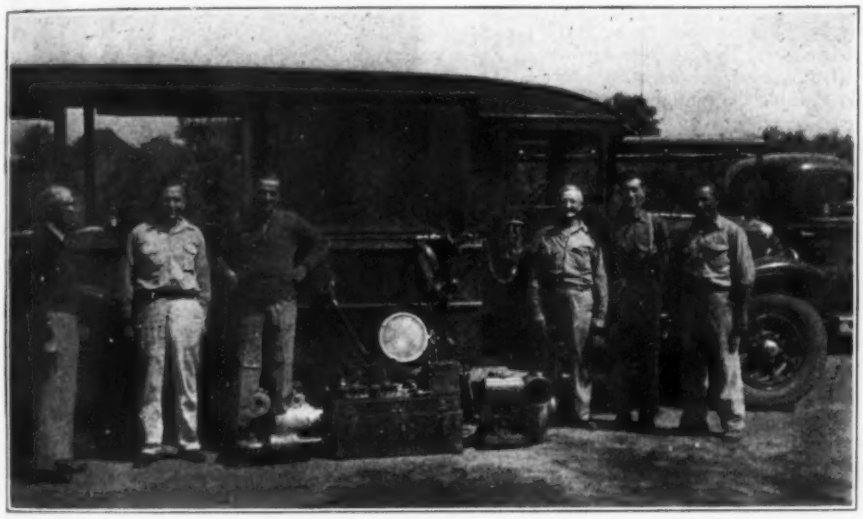
SEWER SERVICE AND MAINTENANCE

Radio Equipped Service and Maintenance Truck Proves Its Value

By EDWARD P. DECHER

Ass't. Secretary and Purchasing Agent
The Joint Meeting, Newark, N. J.

First, it should be explained that the Joint Meeting is a Sewer Commission and is comprised of the following eleven municipalities: City of East Orange, Town of Irvington, Township of Maplewood, Township of Milburn, City of Newark, Village of South Orange, and the Town of West Orange, all being in the County of Essex. In the County of Union are the Township of Union, Township of Hillside, Boro of Roselle Park, City of Summit.



No. 1.—Radio Equipped Maintenance and Service Truck and Equipment (Henry Decher, Ass't Foreman (left) and Crew)

The Joint Trunk Sewer

The Joint Trunk Sewer is constructed within the boundaries of the aforementioned municipalities. The original sewer was built in the year 1900 and is approximately 23 miles in length. A Supplementary Joint Trunk Sewer was completed in the year 1930 to give a total of 54 miles of main trunk sewer in all.

The Joint Trunk Sewer at the present time is serving an estimated population of about 305,000. The Sewage Treatment Plant is located in the City of Elizabeth, the final effluent discharging into Arthur Kill. One can readily see that should our men and equipment be working in the Town of West Orange and an emergency should arise in the Boro of Roselle Park or at our Treatment Plant (the plant being about 12 miles from the Town of West Orange) a difficult task would be encountered in contacting the men or securing needed equipment.

Our Truck Now Radio Equipped

Because of the distances involved it was deemed advisable by the Hon. Peter A. Smith, Chairman of the Joint Meeting, to equip one truck, at least, with a short-wave receiving set for the purpose of reaching our maintenance and service crew in the shortest possible time in case of an emergency or a complaint received which justified attention with least delay.

The radio set was purchased at a cost of $170.00 and installed on our three ton International truck.

The following is a list of the equipment carried on our two motor trucks:

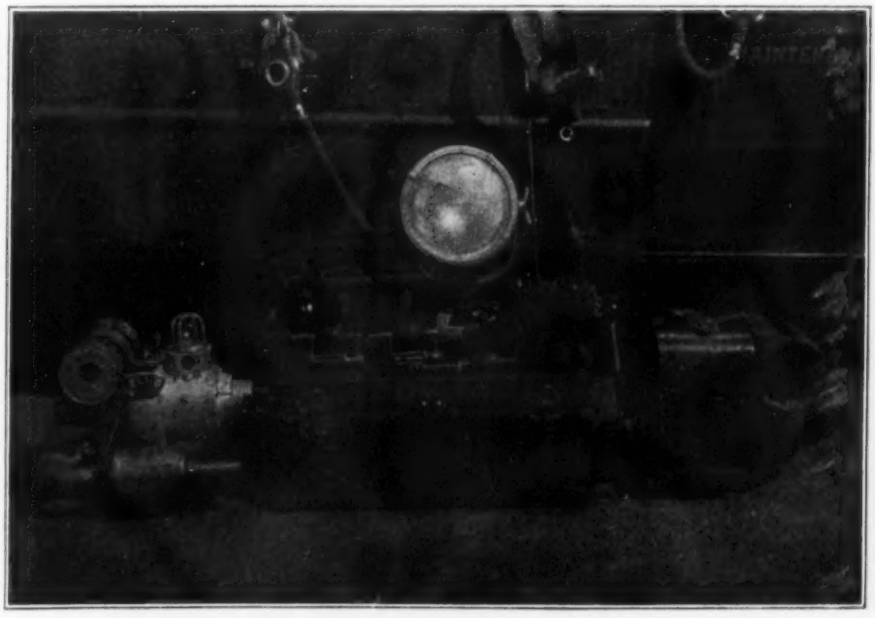
1 Hydrogen Sulfide Detector.
1 Wolf Safety Lamp.
1 Combination Velocity Blower Hose Mask with Safety Harnesses.
1 Carbon Monoxide Detector.
2 Canister Type Gas Masks.
Carbon Monoxide Detector Ampoules.
2 Pairs Chippers Goggles.
1 2½" Portable Air Blower.
1 Combustible Gas Indicator.
1 Industrial First Air Kit.
4 Extra Safety Belts with ropes attached.
Salt tablets for use in the prevention of heat sickness.
1 1500 Watt Portable Electric Generator and Floodlights.

The Joint Meeting has six employees on General Sewer Maintenance (see photo No. 1) and all of these men have taken a course in First Aid which course was given by the Newark Safety Council. Besides being capable of administering first aid, all of the men are trained in the proper use and operation of the many safety devices carried on our equipment at all times.

Our ment are especially instructed in the use of the hose and canister type masks. The Joint Meeting will not permit any of its men to enter a sewer or any sub-surface structure with a *canister* type mask which is of no value in oxygen deficient atmospheres.

We have heard of water service trucks that have been radio equipped. However, at the present time, I know of no other sewer truck equipped the same as the one owned and operated by the Joint Meeting, and I believe that it is the first sewer truck in the United States equipped with radio.

In photograph No. 1 is seen the two maintenance trucks (the larger being the radio equipped unit), some of the equipment



No. 2.—Some of the Equipment (See text for description and uses)

listed above (see Photo No. 2), and the General Maintenance Crew.

Equipment

Portable Generator

On the left is our indispensable Homelite Portable Generator good for 110 volts D.C. and 1250 Watts. In center, the floodlight. Both are products of the Homelite Corporation of Port Chester, N. Y.

With this generator we have several electrical tools and flood lights. These electrical tools have been found to be very satisfactory. We have never at any time found ourselves without proper lighting when emergency work is performed at night. We have approximately 200 feet of special extension cord, should the necessity ever require special lighting in our large sewers when repairs are made. A good portion of our sewers are in outlying territory where electric current to be supplied from a nearby house is impossible.

It may be interesting to note that the Joint Meeting has two cast iron pipe sewers, one being 36 inches in diameter and the other 54 inches, which run parallel and lie on the top of the ground in the Township of Union and each being approximately 1500 feet in length without any manholes. It has been recommended by the Chief Engineer—Leslie E. West—that at least four manholes be built on each line and the type recommended are Hat-Flanges, with bolted covers. To install these Hat-Flanges our portable generator will play a very important part, that is for furnishing the current to drill the necessary holes in the present pipe in order to fasten on the Hat Flanges. If it were not for this machine it would require drilling these holes by hand or renting the equipment.

On two occasions power failures were encountered at the Treatment Plant. We were able to supply the necessary light until the current was restored. Our generator has proven a very sound investment, if not an indispensable one.

Blower, Hose Masks and Gas Detectors

The next item in this photograph is the trunk-like case which contains the blower and the hose type gas masks. This piece of equipment is manufactured by the Davis Emergency Equipment Company, Inc. of New York City. On the top of this case are two carbon monoxide detectors, two hydogent sulfide detectors, and one combustible gas indicator. The last two items of equipment are products of the Mine Safety Appliance Co. of Pittsburgh, Pa.

Portable Air Blower

The last item in this photograph is the portable air blower (on the right) manufactured by the B. F. Sturtevant Company of Boston.

This piece of equipment has proven very satisfactory and is used in ventilating sewers before men are allowed to enter. It has also been used at our Treatment Blant in drying out the tunnels. There also appears on this photograph, hanging from the side of the truck, the headpiece and safety belt of the gas mask. This equipment as shown is carried at all times with the necessary First Aid equipment on this truck. A combustible gas indicator manufactured by the Davis Emergency Equipment Co., together with the duplication of the carbon monoxide and hydrogen sulfide detectors are carried on our other truck, and another set is stationed at our Treatment Plant.

The writer believes that no municipality can afford to be without the necessary safety equipment for the protection of their employees. While the cost of the aforementioned equipment is most reasonable, it is priceless in the event of an emergency.

No. 3.—We find the Flexible Rod to Have Many Advantages Looking into the manhole are Henry Decher, Foreman, and (right) Corey W. Sanford, Superintendent of Sewers.

No. 4.—Pollard's Portable Platform Derrick (On the platform, a turbine wench; Superintendent Sanford, Portable Homelite Generator and Flood Light)

Flexible Sewer Rods

The Flexible Sewer Rod shown in Photograph No. 3 has proven to be a very satisfactory piece of equipment. This piece of equipment, manufactured by the Flexible Sewer Rod Co. of Los Angeles has many advantages, such as can be seen. One can readily understand that the old method used in removing an obstruction in a sewer that only one man could be placed in a manhole, in a cramped position, at a time, thereby reducing his strength to a minimum when working. With a flexible sewer rod you can notice in the photograph that more than one man can be used and greater

No. 5.—Our Chief Engineer, Leslie E. West, Demonstrates the Test for Poisonous and Combustible Gases

pressure exerted, and the safety feature is that the men are on top of the ground at all times during this particular operation. We have found that an obstruction can be moved much faster with this piece of equipment than the methods used heretofore, and that more territory can be covered in a shorter time. There are also many other advantages.

Portable Derrick

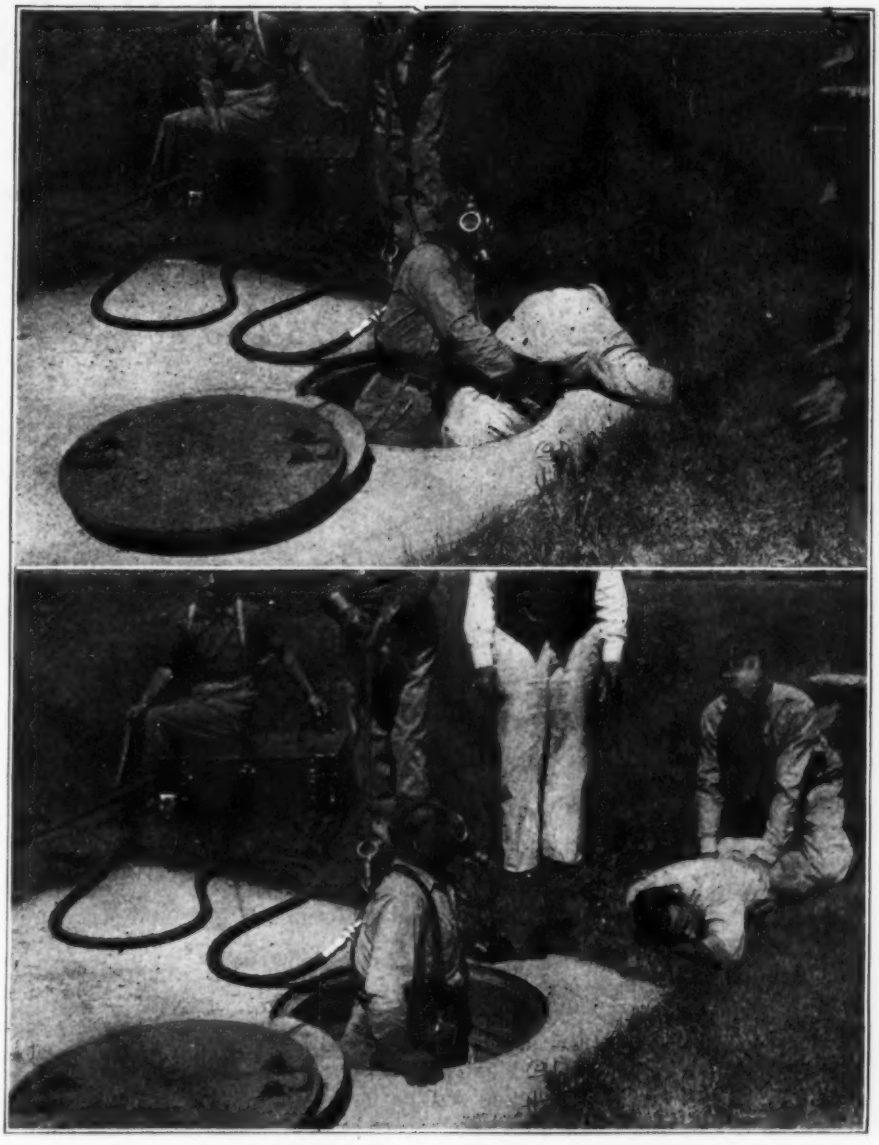
The portable derrick shown in Photograph No. 4, manufactured by The G. J. Pollard Company of Brooklyn, N. Y., is known as the Pollard Portable Derrick. The platform on this derrick is large enough to transport our two Turbine Sewer Cleaning Wenches (Turbine Sewer Machine Co. of Milwaukee) with the drum and cables intact.

These wenches, with the drums and cables, are rather heavy but can be easily placed on the derrick platform without much effort, due to the fact that the platform is only 12 inches above the ground. This platform derrick is equipped with a set of small rubber wheels in the center, and is towed on the rear of our truck from one job to the other.

The derrick has a lifting capacity of 1000 lbs. and can be swung in any position desired. It has been used to lower pipe on some of our repair jobs, and used in raising tilting buckets out of manholes during sewer cleaning operations. It has also been used very successfully in loading heavy manhole heads and pipe on our truck, therefore making loading much safer. This piece of equipment has proved highly useful.

Rescue and First Aid Practice

Photographs No. 6 and No. 7 show our employees giving a demonstration of the proper method of rescuing a man, should he be overcome while working. There may be a possibility that the reader seeing the photograph may criticize the fact that we permitted a man to enter a sewer or chamber without the proper equipment, however, this is not the case with the Joint Meeting. I believe, though, that the fact can be appreciated that it is a hard task to have a man working in a sewer wearing a gas mask continuously, if the conditions under which he is working are absolutely safe. Extensive tests are made before any man is permitted to enter any of our sewers. We have quite a number of meter chambers which are far above the sewer line itself. These must be entered by our employees each week to change the meter charts, and in performing this duty it is not always necessary for a man to be equipped with a mask if conditions are safe, however, one can never tell when an employee may be suddenly attacked by some gas. For this reason our employees must go through a rehearsal such as pictured, so that they do not lose their technique and ability in case of an emergency.



Nos. 6 and 7.—Rescue and Resuscitation Practice Is a Requirement of the Joint Meeting

Compensation Insurance

The Joint Meeting carries compensation insurance, which we believe is very necessary. Regardless of how minor an injury may be, even to a small scratch on the finger, the employee must go to a doctor for the necessary treatment. This is to insure their safety and to minimize claims against the Joint Meeting.

Last year all of the employees of the Joint Meeting were inoculated against typhoid fever. This was paid for by the Joint Meeting as a safeguard to its employees. The Joint Meeting makes every effort to see that its employees are protected from any hazards and makes it a practice to have a safety engineer from the insurance company make regular inspections of the equipment and Treatment Plant every month. And, at the same time the inspection is made a safety meeting is held by our employees, they having an opportunity to discuss problems pertaining to the plant with the safety engineer.

Safety Equipment Demonstrations

In June, 1938 the Commissioners of the Joint Meeting held a special meeting at the Treatment Plant for the purpose of gaining as much knowledge as possible for themselves and the employees on safety measures. The principle speakers at the meeting were Mr. E. M. McCool of the Mine Safety Appliance Co., and Mr. L. W. Brendlen of the Davis Emergency Equipment Co. They gave a very splendid lecture and demonstration on the proper uses of the various safety devices used in connection with sewer work. This meeting was attended by approximately 100 officials connected with the municipal sewer departments in Essex and Union Counties, New Jersey.

Employee Suggestion-Box and Prize Contest

There is installed on the wall in the Treatment Plant a box known as the Suggestion-Box in which suggestions are deposited by our employees. Employees have continuously placed suggestions in this box and, after being given careful consideration, the most practical are tried. A number of the suggestions submitted have been found to be decidedly beneficial. It is a commonly known fact that men in constant contact with equipment are those most able to express its advantages and observe wherein improvements would bring about better results. The Commissioners of the Joint Meeting have discovered that many of these suggestions have resulted in a considerable saving in dollars. For this reason the Commissioners of the Joint Meeting have set up two prizes for a contest which is now in progress, giving each employee an opportunity to express his views as to what in his opinion would better serve the Joint Meeting as operation of the Treatment Plant, maintenance of the sewers, safety of the employees, or any other item pertaining to the works in general.

J. C. FITZGERALD

POST OFFICE BOX 289 • CORAL GABLES 34, FLORIDA

Manufacturer of

The "SEWER SCOOTER" • 100% Self-Propelling Sewer Cleaning Machine

Removes sand, gravel, rocks, bricks, mud, grease, broken rods, metals, etc.

•

Reduces Cleaning Time 75% to 80%

Sewage furnishes the operating power . . . no preliminary work required.

•

The "Sewer Scooter" is a self-propelling combination hydraulic device that operates from the force of the sewage in the sewers. It has all the advantages of a flush tank as it will hold a head of water and discharge it when desired, with the additional advantage that it will move along as the debris is moved in the line. It can be operated with one to two foot head of water in the sewer, but in most places 6" head is sufficient for operation.

The "Sewer Scooter" is designed to pass fixed obstructions extending into the top half of the sewer, such as plumbers' taps and crushed pipe. It will rise up and pass over, or around, obstructions in the bottom and sides of the sewer. This feature enables the machine to pass through places where drag buckets will not go. In some instances it will pass through where the rods can't. In the event several obstructions are passed, and an impassable obstruction is encountered, it can be pulled back through any opening it has entered.

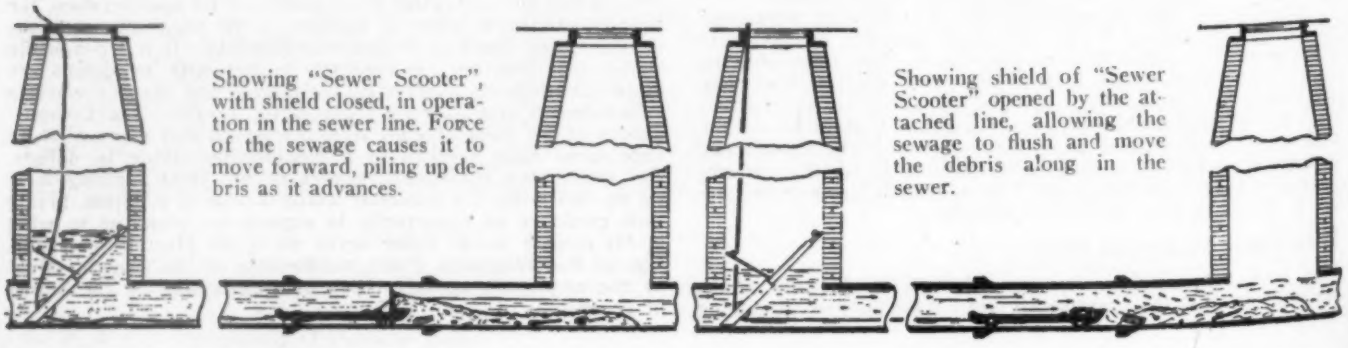
If the "Sewer Scooter" goes through a line just cleaned by some other equipment, it will show the amount of dirt, silt and other accumulations that other machines failed to remove.

The "Sewer Scooter" consists of a wheeled carriage frame with interchangeable shields to fit each size of sewer. It is operated by a line attached to the machine, which is retained on the top manhole level. It is lowered into the sewer line to be cleaned, as shown by the sketch. The shield with its rubber rim seals the flow of the sewage, and as the head builds up the pressure causes the "Sewer Scooter" to move forward until it piles up enough debris to slow its progress. The shield is then opened by the attached line, allowing the sewage to flush and move the debris along in the sewer. As the head drops, the shield is allowed to close and the "Sewer Scooter" advances into the line again. This is repeated all through the sewer line.

When obstructions are encountered too heavy to be moved by flushing, the shield will push them by using the momentum of the moving sewage in the line. This is done by flushing, and when the speed of the sewage reaches its highest point, the line is released allowing the shield to exert this force on the obstructions.

The larger sizes will develop more power than is possible with any other equipment and still have only a small pressure per square inch on the wall of the sewer line.

Showing sand taken from a 21" sewer 320 feet long. The time required was three hours from start to finish.



Showing "Sewer Scooter", with shield closed, in operation in the sewer line. Force of the sewage causes it to move forward, piling up debris as it advances.

Showing shield of "Sewer Scooter" opened by the attached line, allowing the sewage to flush and move the debris along in the sewer.

SOME SEWERAGE OPERATING KINKS

By A. M. RAWN*

Associate Editor, Water Works and Sewerage

SEWER cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. The writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

Sewer Cleaning

The writer in the October, 1935, issue of WATER WORKS AND SEWERAGE described the use of rubber beach balls for cleaning lines up to 30 inches in diameter. Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the district forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face. Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board holding the weights. The sewage backing up behind the "hoe" propels it through the pipe, moving any accumulated debris ahead to the manhole below.

The "hoe" is surprisingly efficient in cleaning the sides and invert of the line. Care must be taken to secure a reasonably close fit between the pipe and the outer edges of the belting so that the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic cleaning ball, described in the October, 1935, issue of WATER WORKS AND SEWERAGE, the "hoe" moves easily over obstructions.

Root Cutting

Many types of root cutters have been manufactured and sold. A number have been tried on the districts' lines. None of them, however, has proven much more efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

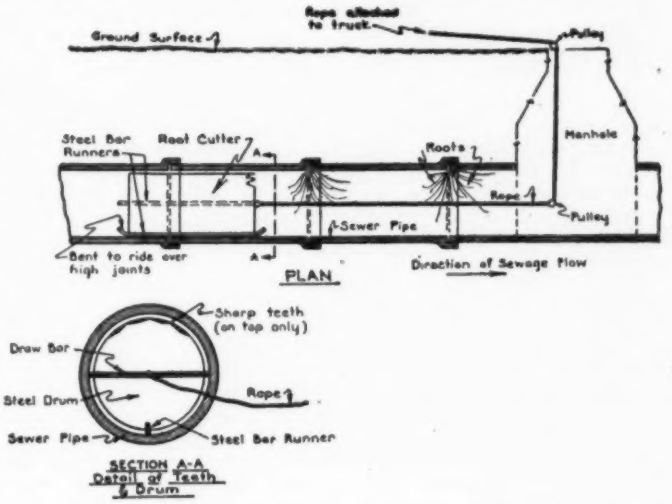


Fig. 2.—Root Cutter for Sewers of 12 to 36 In. Diameter.

*Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles.

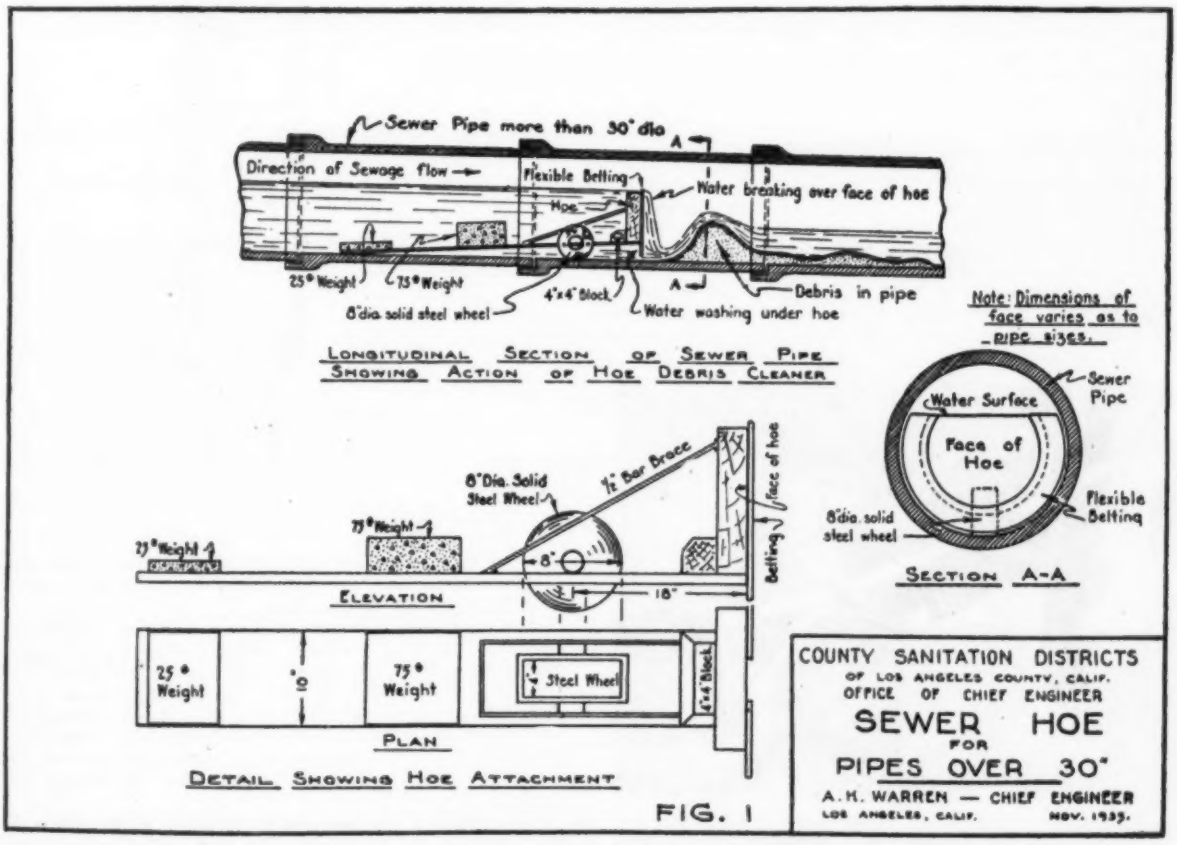


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 In. Diameter.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose as its point of entrance into the line at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.

Air Relief Valve

Fig. 3 illustrates a type of air relief valve used in the 3½-mile (36 in. diam.) effluent pump line leading from the districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 ft. from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

At the district's treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheelbarrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the reaccumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow.

The container or pan may be made any convenient size. That shown holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use

For transporting the pans to the incinerator the pneumatic tire wheel-barrow (illustrated) was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks

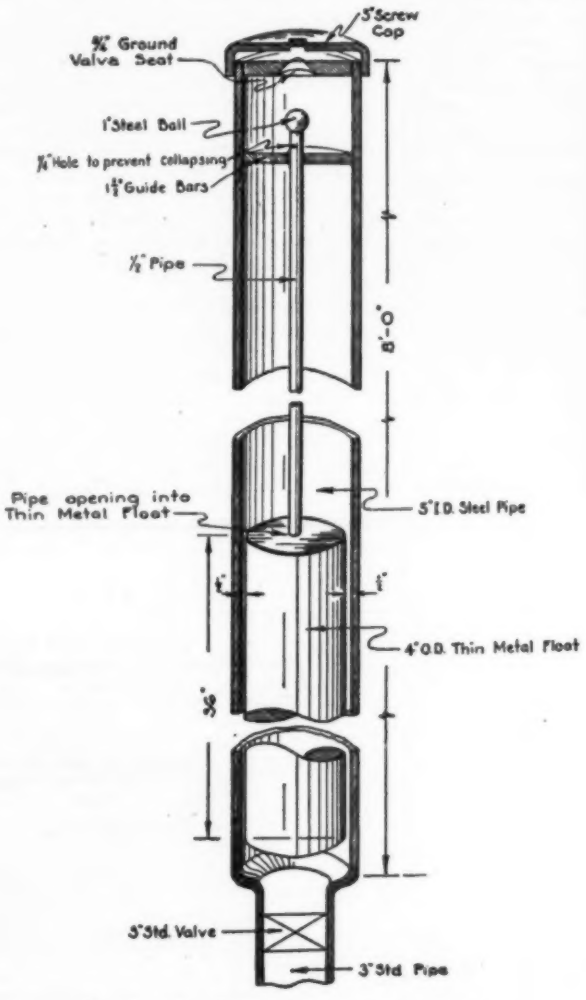


Fig. 3.—Air Relief Valve for Force Main.

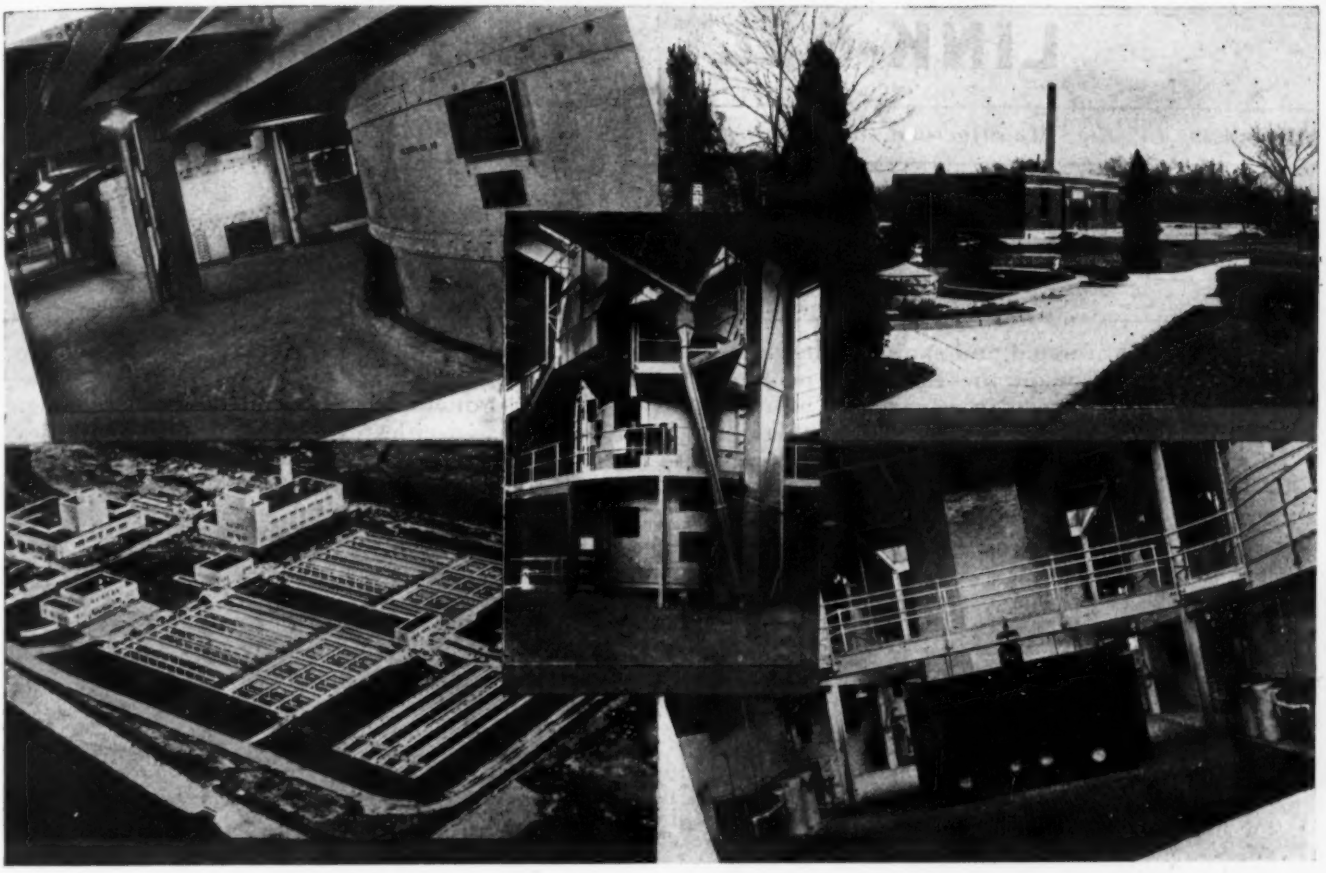
attached to the barrow handles, and the load is securely engaged. The penumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheelbarrow were all built in the plant shop by the plant operators.

Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.



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Literature describing Nichols Herreshoff Incinerators is available and will be forwarded upon request.

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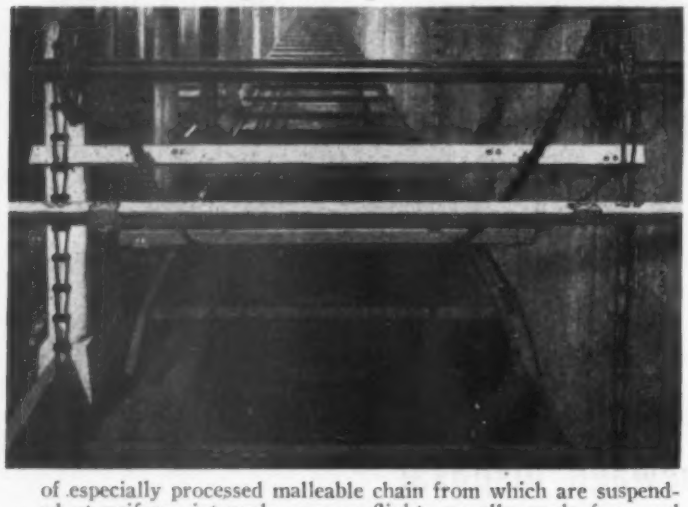
Consulting, municipal and sanitary engineers, and plant operators everywhere are invited to get the latest information on the Link-Belt products for grit washing, mixing and other services. Link-Belt installations are in service at hundreds of sewage treatment, sludge collection, screening, sewage and water treatment plants throughout the country . . . cities . . . towns . . . communities . . . army camps . . . air fields . . . naval bases . . . ordnance works, etc. Catalogs sent on request.

STRAIGHTLINE COLLECTORS

Link-Belt STRAIGHTLINE Sludge Collectors for the removal of sludge from rectangular settling tanks consist of two strands



of especially processed malleable chain from which are suspended at uniform intervals scraper flights usually made from red wood. Features are peak-cap bearings, pivoted flights, cross collectors for larger tanks, and positive sludge removal at a slow, uniform speed. Automatic or semi-automatic skimming equipment is furnished when required.

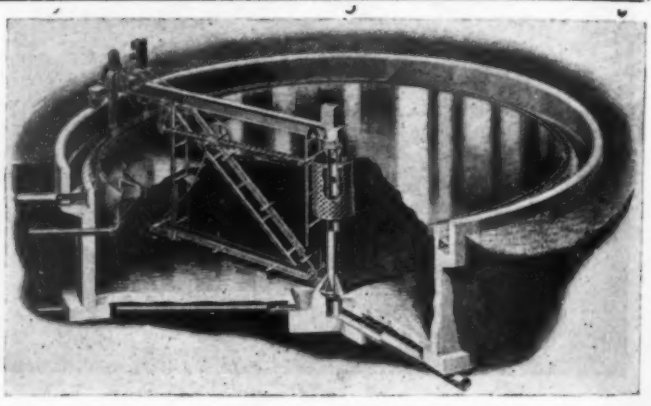
Many installations are now in service in all parts of the country and range in size from the smaller type plants as at Tappahannock, Va., with a capacity of 80,000 G.P.D., to larger installations, such as Ward's Island, N. Y., with a capacity of 180,000,000 G.P.D., and Southwest Plant, Sanitary District of Chicago with a maximum capacity of 600,000,000 G.P.D.

Many features of the Link-Belt STRAIGHTLINE Collector are patented. Send for Book No. 1742.

STRAIGHTLINE MIXERS FOR FLOCCULATION TANKS

Link-Belt STRAIGHTLINE Mixers of the vertical or horizontal type have proved their value in reducing chemical costs and promoting efficient flocculation in water and sewage treatment plants. They consist of a shaft to which is fastened arms which carry either wood or steel paddles that can be pivoted so that the flights can be adjusted to obtain the exact degree of uniform agitation. The maximum circumferencial speed of the mixers for flocculation tanks is 1.8 f.p.s., and the minimum speed is about half of that. A gradual decrease in speed of the units is desirable for efficient flocculation.

Send for Book No. 2042.



Drawing of Link-Belt Type "B" Circuline Collector.

CIRCULINE COLLECTORS

Link-Belt CIRCULINE Collectors for the removal of sludge from round tanks consist of a flight conveyor suspended from a bridge, one end of which is pivoted at the center and the other end is mounted on standard rubber-tired wheels which travel around at circumference of the tank. Features are: positive, slow, uniform speed; positive sludge removal and excellent distribution of flow throughout the tank; improved automatic scum collecting screw conveyor and scum receiving hopper as standard equipment. Made in two standard sizes — Type "B" for Tanks up to 55' dia.; Type "A" for larger sizes up to 200' dia. Send for Book No. 1982.

Link-Belt Type "A" Circuline sludge collector in 70-ft. diameter final settling tank at an army camp sewage treatment plant.

BIO-FILTRATION SYSTEM FOR TREATING SEWAGE

STRAIGHTLINE Collectors in primary and secondary settling tanks at Bio-Filtration Plant, Camarillo, Calif.

Bio-Filtration Sewage Treatment System with Link-Belt STRAIGHTLINE and CIRCULINE Collectors brings new advantages. The system consists of high rate shallow filter beds and recirculation of the effluent from the filter beds to the primary tanks. Features are great flexibility, high rate of B.O.D. loading and the ability of such a plant to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. A large number of installations of this type are now in operation. Send for Folder No. 1881.

STRAIGHTLINE BAR SCREENS

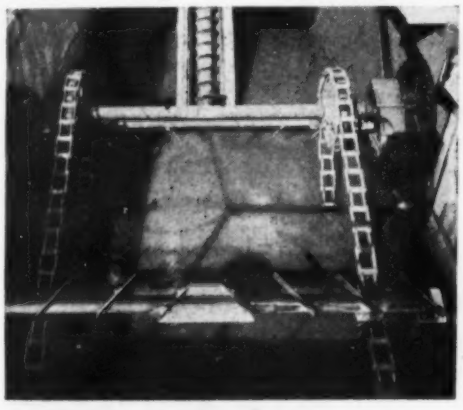
Link-Belt STRAIGHTLINE Mechanically Cleaned Bar Screens have spaced parallel bars on which the larger floating solids in incoming sewage collect, and a mechanically operated rake for removal of the accumulating solids, thus assuring an even flow of sewage through the channel. The machine may be set vertically or inclined, and used in small or large plants.

STRAIGHTLINE Mechanically-Cleaned Bar Screen at Sewage Pumping Station, Lackawanna, N. Y.

Send for Booklet No. 1587.

STRAIGHTLINE GRIT COLLECTORS AND WASHERS

The Link-Belt STRAIGHTLINE Grit Collector and Washer collects the settled grit and frees it from putrescribe organic matter. This unit consists of a scraper type collector with pitched flights, and an inclined washing and dewatering screw to which the collector conveys and into which it discharges the grit at bottom of tank. Send for Book No. 1942.



INDUSTRIAL WASTE SCREENS

The Link-Belt Industrial Waste Screen is an efficient and economical unit for the removal of objectionable suspended solids from industrial waste before the water is discharged into sewers or streams. The screenings come off the machine with a minimum of moisture. Units are available in several sizes and with coarse or fine screen medium. Wastes from canneries, textile mills, steel mills, etc., are handled successfully by these screens. Send for Book No. 1977. We also manufacture rotary screens for similar service.

This "Liquid" waste screen separates refuse from water as received from beet pulp washers before discharging to sewage system.

TRITOR SCREENS

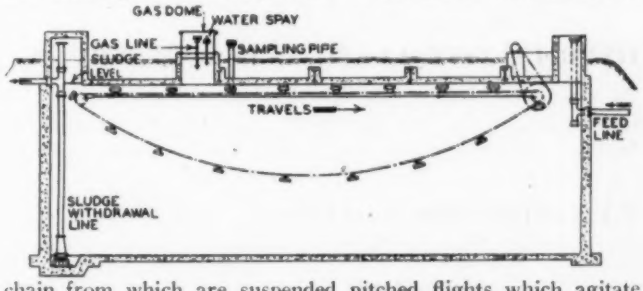
The Link-Belt Tritor Screen, is a combination of screen and grit chamber. It is especially designed for medium and small size plants. Its main elements are a hopper, a bar screen, and a bucket elevator for removing grit from hopper, the buckets being perforated for drainage. On return run, rake teeth on buckets clean the screen. Adjustable baffles regulate velocity of flow through the hopper.

Booklet No. 1587.

TRITOR Screen, fully-enclosed type, at Salisbury N. C. Sewage Plant.

STRAIGHTLINE SCUM BREAKERS

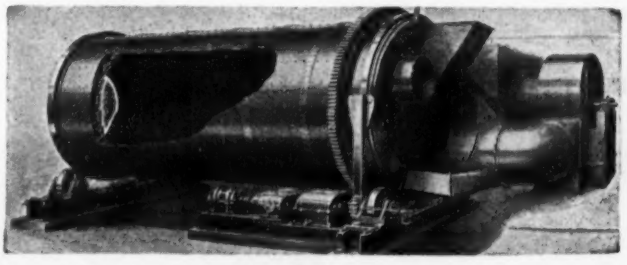
The scum breaker is used in digestion tanks to paddle down and submerge the floating scum. It consists of two strands of



chain from which are suspended pitched flights which agitate the scum and carry it below the surface of the supernatant liquor. Features are rugged construction and automatic take-up where required.

ROTO-LOUVRE HEAT DRYERS

The Link-Belt Roto-Louvre heat dryer consists of a mechanically rotated horizontal drum with a series of internal channels near the circumference into which hot air enters, leaving then through slots to enter the inside of the drum, which contains the sludge; hot air entering the channels only when they are near the bottom, and thus all passing through the sludge. Due to this intimate contact of drying medium with material, high efficiency is obtained keeping flow space requirements at a minimum. Dry material discharges from dryer at a low temperature of about 150° F and the unit is equipped with automatic controls that maintain the desired discharge moisture content. No cascading takes place, thereby minimizing degradation and wear. Send for Book No. 1911.



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OTHER LINK-BELT WATER PURIFICATION and SEWAGE TREATMENT PLANT EQUIPMENT INCLUDES: Rotary Screens; Traveling Water-Intake Screens; P.I.V. Gear Variable Speed Drive for Pumps; Coal and Ashes Handling Machinery; Car Spotters and Haulage Systems; Shovel-Cranes-Draglines—Crawler and Wheel-Mounted types; and a complete line of elevating, conveying, materials handling and power transmission machinery. Catalogs on request.

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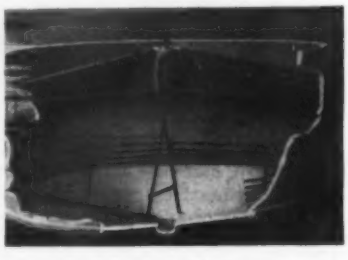

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P.F.T. has available several efficient types of circular spray sewage nozzles for application to the risers in sprinkling filter beds. Easy to install and clean. Designed to minimize clogging, and afford uniform distribution. Detailed in Data Book No. 130.

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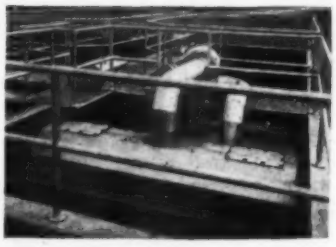
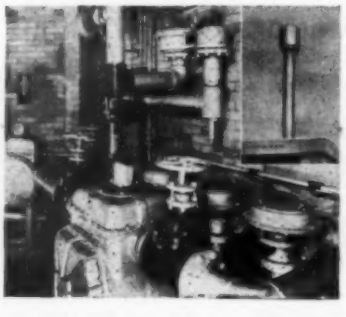
Provide an economical means of securing efficient air diffusion in activated sludge aeration tanks. These cast iron units make a simplified permanent air diffusion system with provision for easy removal and maintenance of diffuser plates. Insure uniform air distribution throughout full length of tank. Write for data.

P.F.T. ATOMIZING TYPE AERATORS



have three applications. (1) Supernatant liquor treatment; essentially an aerator settling tank unit which re-returns to the head of the plant a treated effluent which will not cause operating difficulties. Bulletin 142. (2) Pre-treatment of laundry and trade wastes; as a combination aerator-settler unit which reduces grease content, suspended solids and B.O.D. Bulletin 141. (3) Pre-aeration and grease removal; consists of a surface chamber to which a vacuum is applied as a means of mixing atomized liquids and solids with a large volume of free air. Unit is mounted in a small section of the primary clarifier. Bulletin 140.

P.F.T. SLUDGE GAS CONTROL EQUIPMENT



Consists of Flame Traps, waste gas pressure relief flame traps, waste gas burners, pressure gauges and other boiler room and accessory equipment designed to eliminate explosion hazards and to insure constant pressures. P.F.T. Flame Traps have renewable elements which permit passage of gas but not flames. Valve in line is closed when heat is sufficient to melt fusible plug. All described in Bulletin 121-A.

SEWAGE TREATMENT PLANT OPERATION

Compiled from Various Sources

By A. P. BANTA

Asst. Engr., Los Angeles County Sanitation Districts, and
Asst. Prof. San. Eng., California Inst. of Technology
Pasadena, California

A DAILY inspection of each major unit of the plant by the plant operator should be made, any unusual conditions recorded, and faulty conditions immediately remedied. The plant operating data should be fully compiled each day, and kept, as an aid in maintaining the plant in proper operating condition. Such records are valuable for future reference and as evidence.

It is especially important that the daily flow or rate of flow of sewage reaching the plant be measured and recorded. Methods commonly employed to determine sewage flow are as follows:

1. Weir measurements.
2. Counters on dosing tanks of known capacity.
3. Capacity of pumps and period of operation.
4. Recording meters (Venturi, weir, etc.).
5. Dosing tank period for filling.

Records of power consumption and supplies, tools or chemicals obtained should be maintained. A daily log book for keeping such records and information concerning general or unusual conditions is very useful.

The air temperature, wind direction and general weather conditions should be recorded daily. This information is valuable in the investigation of nuisance complaints such as odors.

It is also essential that a few simple tests be made to determine the efficiency of separate units of the plant or of the plant as a whole. The results of these tests and a record on operation will:

1. Indicate to the operator whether the plant is or is not functioning properly.
2. Aid the municipality or institution in case of law suits resulting from alleged pollution or nuisance.
3. Assist consulting engineers in planning changes or additions to the plant.
4. Enable the officials responsible for the operation of the sewage disposal plant to prepare reports to the public and to the State Department of Health on the operation and efficiency of the plant.

The operator should have for ready reference plans or blue print designs of the plant, showing the dimensions of each unit and all pipes, valves, gates, etc., in order that he may be able to fully understand the construction and operating details of the plant.

A competent sanitary engineer can materially improve operating conditions through guidance and advice. It would be advisable for municipal or other officials to retain consulting engineers, or an experienced operator from a nearby plant, for a few years after completion of a new plant in order to supervise plant operation. Operating difficulties may frequently be prevented or readily corrected by following their advice.

Operators of sewage treatment plants should always remember that sewage gases are combustible and also explosive under certain conditions. Such gases may be toxic and asphyxiating. It is, therefore, necessary to take unusual precautions where such gas may be present either in the sewer system or at the treatment plant. No open flames or other sources of ignition should be permitted. Adequate ventilation of manholes and other similar enclosures before entering is always advisable. Moreover, no one should ever enter a place where such gases are likely to be present without an emergency rope attached to his person and two watchful attendants stationed outside. When the gases are toxis, i. e., containing poisonous gases, a special gas mask should also be used.

The following are a few fundamental details of the proper operation of sewage treatment plants. Local conditions may alter somewhat the following operating details but in general these notes give a resume of the operating procedure for the various types of treatment described.

Grit Chambers

1. Grit chambers should be cleaned after every large storm.
2. Grit chambers should be cleaned whenever tests show that the grit compartment (the compartment below the inverts of entering and outlet channels) is filled with hard material to 50 or 60 per cent of its capacity.
3. The grit should be promptly disposed of by burying it or drying it on sludge beds. If it is sufficiently clean, it may be used for filling in low land.

Coarse Screens (½-Inch to 3-Inch Openings)

Screenings, unless properly disposed of, are frequently a serious source of nuisance at a treatment plant because they decompose readily, giving off obnoxious odors. They will also encourage the breeding of rats and flies unless properly cared for. Furthermore they are unsightly and repulsive to visitors.

1. Remove the screenings twice daily or oftener if necessary to prevent clogging of the screen and consequent backing up of sewage in the outfall sewer.
2. Promptly dispose of screenings by:
   (a) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with borax, chloride of lime, or other disinfectant and covered with earth as early as possible.
   (b) Incineration where possible.
   (c) Grinding, either returning ground material to the sewage flow or mixing it with the primary tank sludge going into digesters.
3. Clean the screen chamber, removing all accumulated sludge and grease, at least once a day.

Fine Screens (½-Inch or Less)

1. Fine screens are usually continuously mechanically cleaned, either by water, air or revolving brushes, and therefore all moving parts should be properly lubricated to keep them in proper working condition.
2. Remove and dispose of screenings promptly by:
   (a) Mixing with garbage and incinerated.
   (b) Dewatering by pressing, and then incinerating or burying the solids.
   (c) Burial, covering by at least 12 inches of earth, either by ploughing under the soil or shallow trenching. They may be placed in trenches, treated with chloride of lime, or other disinfectant, and covered with earth as early as possible.
   (d) Digested with other solids removed by sedimentation.

Septic Tanks

1. Sludge and scum should be removed whenever they accumulate to a combined depth equal to ¼ the depth of the tank below the flow line.
2. Sludge should be removed when large suspended particles are observed in the effluent, or when the daily test of settleable solids in the Imhoff cones shows any appreciable increase of settleable solids in the effluent.
3. All inlet and outlet channels, pipes, weirs, valves, etc., should be kept clean and free from accumulations of grease and grit.

Mechanically Cleaned and Plain Settling Tanks with Separate Sludge Digestion

(A) Plain Settling Tanks:

1. The settled solids should be completely removed at frequent intervals, at least twice daily, from the settling tanks to the separate sludge digestion tanks. Mechanical equipment installed for the collection of sludge should be operated for a sufficient length of time before drawing sludge to insure complete removal of the deposited solids.
2. Septic action in the plain settling tanks as evidenced by "gassing" or rising sludge or an appreciable increase of settleable solids in the settling tank effluent should be avoided by prompt and regular removal of sludge to the digestion tanks.

3. Grease and scum should be removed at least daily, using the mechanical skimming device or by using a perforated hand-skimmer and the tanks should be maintained in a clean appearing condition at all times.

(B) Separate Sludge Digestion Tanks:

1. The contents of single tanks should be stirred or agitated at intervals by recirculation or other means to assure proper "seeding" of the fresh solids and to afford rapid and efficient digestion. Such stirring also lessens the chance of acid production, "foaming" difficulties, and excessive scum formation. Where there is surplus capacity or stage digestion this operation is of doubtful benefit.
2. Where heating coils or other adequate means of heating the contents are available, the temperature should be maintained at about 85° F.
3. The amount of fresh solids added daily should not be over one twentieth (5%) of the amount of "ripe" sludge in the tank, on the basis of the dry solid content of each.
4. Care must be used in removing digested sludge to avoid the removal of such a large amount that the ratio of "ripe" sludge to fresh sludge added drops below twenty to one.
5. By concentration tanks or otherwise the solids content of the sludge added to digesters should be as high as is practical to avoid loading the digesters with liquid which reduces the time of the solids in the digesters, creates undue disturbance and chills the contents. This matter is far more important than is generally realized.

Imhoff Tanks

1. Sedimentation Compartment:

(a) Grease and scum in the sedimentation compartment should be removed daily. This is best accomplished where no mechanical means is provided, by the use of a dish-shaped perforated skimmer. Such grease and scum should be promptly disposed of by burying or burning. Where objectionable conditions are not likely to develop, the grease and scum may be placed in the gas vents.

(b) The sides and slopes of the sedimentation compartment should be carefully scraped with a rubber squeegee and all solids pushed down through the slots at least twice a week.

(c) The slot in the bottom of the sedimentation compartment must be kept open and free from obstruction of any kind. At least once a week the slot should be cleaned by the use of a heavy chain drag, taking care to traverse the entire length of the slot.

(d) Failure to carefully follow the foregoing operating procedure will usually result in an effluent of inferior quality and where a trickling filter is used there will be deposits and accumulation of solid material on or in such filter, due to grease, scum or sludge being carried through the tank.

(e) Where the design of the tank will permit, the direction of flow through the sedimentation compartment should be reversed at least once a month, in order to distribute the solids uniformly in the digestion or sludge compartment.

2. Gas Vents or Scum Compartment:

The scum in the gas vent should be broken up at least weekly to afford an easy escape for the gas from the digestion or sludge compartment. Control of the scum may be accomplished by some of the following treatments:

(a) Breaking the scum up with a hoe, rake, or other suitable tool.

(b) Hosing the scum in the gas vents with water under pressure.

(c) Punching holes through the scum at two-foot intervals with a wooden pole.

(d) The scum may be removed and dried in a sludge drying bed if its depth approaches 2 to 3 feet in the vents. Usually it burns readily and if incinerated may create a hazardous flash, due to grease content.

(e) Treatment of the scum in the gas vents daily with hydrated lime at a rate of about 10 lbs. per 1,000 population has been found to be helpful in controlling excessive scum formation and to aid in maintaining the pH value of the digesting sludge.

3. Sludge Compartment:

(a) The height of the sludge in the sludge compartment should be determined at inlet and outlet ends of the tank at least once a month. The use of a pump for this purpose is the most desirable and satisfactory. The use of the plate or disc method is not usually satisfactory. The following are suitable methods for measuring the depth of sludge:

(1) One method involves the use of a pitcher pump provided with a rubber suction hose, weighted on the end and the length marked on the hose at intervals of 2 feet, measuring from the weighted end toward the pump. The hose is gradually lowered through the slot in the sedimentation compartment, meanwhile constantly pumping, and the length of immersed hose, when sludge first comes through the pump is determined. When the sludge elevation is reached, the pump will usually "choke" before sludge appears.

(2) The sludge depth may also be determined by use of an iron plate or weighted wooden block, about 12-18 inches square, attached to a wire or chain lowered through the gas vent. The plate or block will stop when the sludge is reached and the distance from the surface to the sludge level is determined from the graduated wire or chain by which the device is lowered. The pump method is by far the most positive procedure.

(b) Sludge should be removed:

(1) Whenever the sludge depth approaches within 18 inches of the slot in the sedimentation compartment.

(2) In small amounts at frequent intervals rather than in large amounts at longer intervals. Usually some sludge should be drawn every month.

(c) Sludge should be removed at a slow regular rate to avoid the formation of a channel through the sludge in the sludge compartment and the withdrawing of partially digested sludge or the liquid above the sludge.

(d) If sludge does not flow readily, it may be started by:

(1) Agitating with water under pressure through perforated water pipes in the bottom of the sludge compartment, if such pipes are available.

(2) Applying water pressure through hose immersed into the sludge compartment or through the sludge riser pipe.

(3) Agitating around sludge inlet with long rods through the sludge riser pipe.

(e) Avoid withdrawal of all the sludge from the tank. Leave sufficient digesting or "seed" sludge to prevent the difficulties incidental to starting a new or completely cleaned tank. Usually not over half the depth of sludge in the tank should be removed at any one time.

(f) After use the sludge pipes should be flushed out and refilled with water or sewage to prevent the sludge from hardening and clogging the sludge pipes.

4. "Foaming:"

There are a number of possible causes for "foaming" such as industrial wastes like milk or cannery wastes, "mash" or "wine" wastes, drawing out too much sludge at one time, or increased temperatures in the sludge compartment. Foaming is almost invariably associated with an "acid" condition of the sludge and in such cases may be minimized or corrected by treatment to counteract the acidity. However, there is such a thing as alkaline foaming but it is not common.

When foaming occurs, there are a few simple treatments which may under certain conditions remedy or improve the condition.

(a) Relief may sometimes be obtained by drawing some sludge.

(b) Hosing the gas vent area with water under pressure will sometimes help.

(c) Cutting the tank out of service if possible and allowing it to rest will permanently improve conditions.

(d) Paddling the foam with long-handled hoes is also temporarily effective.

(e) Hydrated lime added through the gas vents at daily intervals will frequently correct a foaming condition.

(f) Treatment of the raw sewage with chlorine at rates of 20 to 50 pounds per million gallons will often bring foaming under control.

Trickling or Sprinkling Filters

1. The nozzles should be inspected daily. All clogged nozzles should be cleaned and any broken nozzles replaced.
2. The surface of the filter bed should be kept free from plant growths.
3. The formation of ponds or "pooling" on the surface of the

filter bed may be remedied or prevented by:
(a) Flushing the surface of the filter with a fire hose.
(b) Raking or forking the surface of the filter bed.
(c) Punching holes through the top layer of the filter medium with iron bars.
(d) Heavy applications of chlorine, chlorinated lime or other chemicals for short periods applied directly to the bed surface or in the filter bed influent at the dosing tanks. The treatment is usually most effective and economical if applied to the low night flows of weak sewage.
(e) Operation of units may sometimes be improved by cutting them out of service occasionally for a period of 12-48 hours.

4. Where the design of the filter bed will permit, the presence of large numbers of filter flies may be controlled by periodic flooding of the filter beds. Chlorine application, as for ponding, is also very helpful but not a 100% effective remedy. In flooding the sewage it should be chlorinated to delay oxygen depletion and septic action during the holding period.
5. The distribution piping should be flushed periodically.
6. The underdrains should be flushed out occasionally with water hose or other suitable flushing devices, if the filters are so constructed as to make this possible.
7. Where revolving distributors are installed, frequent inspection of water or mercury seals should be made.
8. Where revolving distributors are installed, the flow from the nozzles should be adjusted so that the flow delivered is proportional to the area covered, i. e., the end nozzle should deliver twice as much as the one half-way out from the center. The center nozzles should deliver very little flow—only thin share for the ratio of area covered.

Secondary or Final Settling Tanks

1. The sludge should be removed frequently to prevent septic action and gasification of the solids which results in discharge of solids with the final effluent. This cleaning is usually necessary at least once a month, or oftener, during the summer season.
2. The depth of the sludge should be determined at frequent intervals by the use of a sludge sounder or other device.
3. The sludge may be disposed of in the same manner as sludge from primary settling tanks, i. e., pumped into primary settling tanks or into separate sludge digestion tanks direct for digestion. In the latter case density of the sludge is an important consideration to perclude the effects of dilution on the digesters.

Sludge Drying Beds

1. Sludge beds should not be filled to a depth of more than 12 inches or to such a depth that the sludge cake cannot be removed within two weeks in good drying weather.
2. The surface of the drying bed should be kept clean and free from all previously discharged sludge. *Never discharge wet sludge upon dried or partially dried sludge.*
3. The surface of the sludge drying beds should be kept nearly level to afford an even distribution of sludge over the surface of the bed.
4. Dried sludge may be used for fill, buried, or spread upon the ground, where it will not be carried into a stream or watercourse by rain.
5. In many communities the sludge is readily disposed of by giving or selling it to nearby farmers for use as fertilizer. This should be encouraged as sewage sludge has been found to have fertility and soil improving values. It is not advisable, however, to use it for the fertilization of crops which are served in an uncooked condition. For best results the sludge cake should be shredded or pulverized before attempting its sale.

Sand Filters

1. The beds should not be used continuously but sufficient time should be allowed between doses for the bed to drain thoroughly and "rest" between applications. Satisfactory operation of a filter bed depends on the presence of oxygen in the bed and therefore opportunity for the entrance of air into the bed must be provided by the "rest" periods.
2. The beds should be periodically cut out of service, allowed to dry and the surface raked or scraped clean.
3. "Pooling" should not be allowed to develop on the beds as this tends to produce septic action, obnoxious odors and an effluent of poor quality. Pooling indicates that cleaning is necessary. Frequently a harrowing is all that is required. Eventually skimming will be required.
4. The surface of the beds should be kept level to afford uniform distribution of the sewage.
5. Weeds, grass, etc., should not be allowed to grow on the beds.
6. The depth of the bed should be maintained by removing during cleaning only the least possible amount of sand. Once a year clean sand should be added to replace that removed during the year.
7. Where natural sand percolation beds are used it is sometimes advisable to shallow harrow the beds after careful removal of all organic deposits.

Chlorination

The purpose of chlorination is to prevent bacterial contamination of streams or other bodies of water, used for municipal or industrial water supplies, irrigation, shell-fish growing, recreation or bathing.

The effective chlorination of sewage or sewage effluents depends upon the presence of adequate quantities of chlorine at *all* times in all portions of the sewage for sufficient time to provide the necessary period of contact between the disinfectant and the bacteria in order that disinfection may be efficient.

The strength of any sewage varies greatly with seasonal changes, with the days of the week and during the hours of the day. The amount of chlorine required varies accordingly.

1. Chlorine should be applied in such quantity that there will be a residual of at least 0.5 p.p.m., as determined by the ortho tolidine test, after 15 minutes contact of chlorine with the sewage or the effluent, depending upon whether pre- or post-chlorination is practiced.
2. The test for residual chlorine should always be made at the time when the sewage or effluent is the strongest or when it requires the largest amount of chlorine for treatment.
3. Weigh chlorine tank each day at the same time to determine the amount of chlorine used during the preceding 24-hour period.
4. The chlorine must be applied *continuously* in the proper quantities.
5. Before connecting a new chlorine cylinder to the control apparatus, blow off some of the chlorine from the new cylinder into the air in order to prevent clogging of the apparatus. Store the empty cylinders apart from the full ones so as to avoid mistaking empty cylinders for full ones.
6. Examine the chlorine apparatus daily and if any trouble is found which cannot be corrected by the operator, notify your superior at once.
7. It is not advisable to draw chlorine from any one cylinder at rates higher than 40 lbs. of chlorine in a 24-hour period, because of the danger of "freezing" and slowing up the chlorine flow. If more chlorine is necessary, two or more containers should be connected and used in parallel.
8. The operator should always have on hand a stock of the usual replaceable parts for the chlorine apparatus and a reserve supply of chlorine cylinders.
9. Leaks in the chlorine apparatus should be promptly repaired to prevent corrosion of the equipment and structures. Such leaks may be detected by the formation of white fumes when tested in the immediate vicinity with the vapors from an ammonia solution. (Household ammonia is satisfactory).
10. During cold weather heating facilities should be provided to maintain a temperature of 60° F. and never less than 50° F., in order to prevent so-called "freezing" in the chlorinator and stoppage of the chlorine flow. It is frequently necesssary to heat the water supply to the tray of the chlorinator to prevent "chlorine-ice" formation.
11. Chlorine is a liquid when under pressure in the cylinders and is an irritating gas which is heavier than air when released. It may produce serious after effects if inhaled. A satisfactory gas mask should be available at all plants where chlorine is handled.

Activated Sludge Tanks

1. Sludge percentage tests (settling for ½ hour a liter graduate) should be run twice daily on the mixed liquor of the aeration tanks, sampled at the half-way point.
2. When the sludge percentage of the mixed liquor exceeds 30% (300 c.c. in the liter graduate), sludge should be withdrawn. Some plants have been found by experience to operate more efficiently at a lower per cent.
3. Excess sludge should be wasted into the raw sewage if primary sedimentation is practiced or wasted directly to digesters or via thickener tanks if these are provided. Such tanks are an important adjunct to the functioning of digesters.
4. Direct drying of untreated sludge results in odor and fly nuisance.
5. For small plants, dissolved oxygen tests on the effluent

from samples taken from the clarifiers should be run daily. B. O. D. and suspended solids tests on the effluent should be run at least twice weekly.

6. Cracked or leaking air diffusion plates should be watched for and quickly repaired.
7. Air and sewage regulating valves should be operated at least once a month to insure against sticking.
8. Bulking is said to occur when unusual amounts of suspended solids pass out with the effluent. It may sometimes be controlled by one of the following practices:
   (a) Increasing the supplied air or reducing the solids carried in the aeration units.
   (b) Continuously adding lime sufficient to bring the pH up to 9.0 (for small plants).
   (c) Adding small amounts of fine clay (for small plants).
   (d) Moderate chlorination of the returned sludge.
   (e) Bypassing the sewage until condition is corrected.
   (f) Eliminating industrial wastes from the sewerage system when these are proven to be causative.

If bulking becomes a chronic problem, the administrative authority should be fully informed and an investigation by a competent sanitary engineer recommended.

9. Air pressure on this diffuser manifold should be recorded regularly, as increase in pressure results in increased power cost.
10. Operation of final settling tanks is similar to operation of primary settling tanks.

Neatness, Cleanliness, Beautification

1. It is very easy for a sewage plant operator to become negligent. The appearance of his plant reflects in most cases his own character.

2. A limited planting of shrubs and trees will add greatly to the appearance of a plant. Most administrative authorities, if properly approached, will provide at least in a small way, for this improvement. Select hardy plants which require a minimum of attention.

3. Paint is an investment. A plant where painting is neglected will soon require expensive replacements. Learn all you can about paint; many conditions require special paint.

4. A set of neat, well-kept records is a convincing argument when an operator is asking for improvements.

5. A clean plant is usually a well-run plant.

6. An untidy plant is a hazard to life and limb. Slippery steps, unused equipment left in the way, can be the cause of a nasty fall.

7. Work around sewage is always subject to health hazard; extra care and cleanliness are, therefore, essential. A first-aid kit should be on hand and used for even minor injuries. Arrange for prompt medical service for more serious accidents.

8. Make a study of the life cycle of flies and mosquitoes. A knowledge of this subject will enable an operator to control with a little thought and effort, most insect nuisances.

Last but Not Least

9. Join and take an active part in your local sewage works association. The journals and the exchange of operating experience with other members is a rich source of progressive ideas.

Acknowledgement—This paper constituted a lecture in the Water and Sewage Tanks Operators Short Course of the 11th Annual Institute of Government at the University of Southern California, Los Angeles

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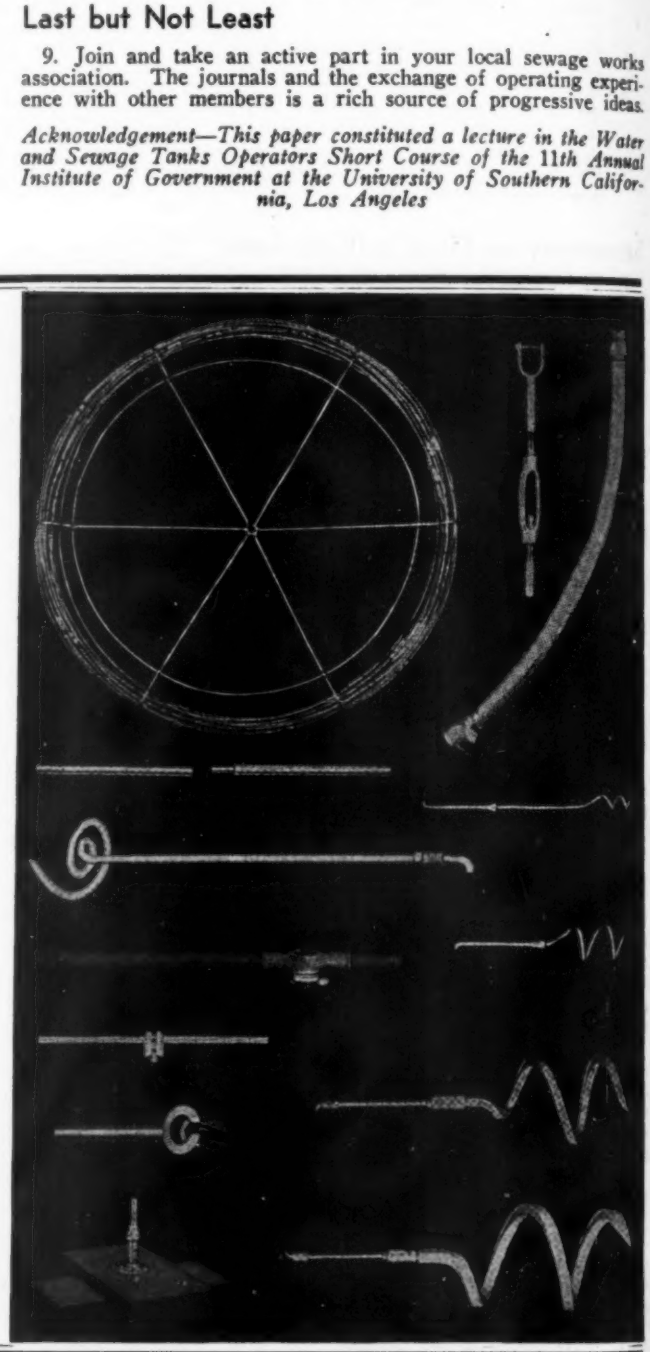

MEASUREMENT OF FLOW IN OPEN CHANNELS

Parshall Flume, Using "Free Flow" Condition Gives Ready Measurement for Silt-Bearing Waters or Sewage

By J. TARRANT
Ruislip, England

THE Parshall measuring flume described by R. L. Parshall in Bulletin 423 of the Bureau of Agricultural Engineering has been proved to be a reliable method of measuring the flow of water in channels, and is especially useful where the water carries solids in suspension.

The older method of measuring the flow in channels by means of weirs or notches has the disadvantage that the barrier across the channel carrying the weir or notch forms a pocket where sediment may collect, with detrimental effects on the accuracy of measurement. The Parshall flume has no such obstructions and can be so proportioned that the velocity of flow carries forward the silt and maintains a clear channel.

There is also the question of head loss which, when pumps are used for delivering water or sewage on to a plant or when it is desired to avoid pumping, may be an important consideration. The head lost in a flume, by utilizing the full allowable submergence at the outlet, is very considerably less than that imposed by the use of a weir or a notch.

The principle of measurement is similar to that of the weir in that the head over a sill is measured, and this measurement is used either alone or in conjunction with a second head reading taken downstream of the sill for the estimation of the rate of flow. The use of two readings means that (because the downstream head may rise to a value equal to about 95 per cent of that upstream) the loss of head can be reduced to an extremely low figure, but the indicating or recording of the flow is complicated as compared with either by a single head reading.

Head Loss

When measuring the flow by a single head (the "free flow" condition) the loss of head may not be reduced below a figure which is a percentage of the head on the sill for each rate of flow. (The figures are given later.) This head loss is such that the level of water downstream is not allowed to rise to the point where it will have any effect on the volume of the discharge as indicated by the head on the sill. That is to say, for a given head on the sill the flow remains constant as the tail or downstream water level is progressively raised until, at a certain submergence, the flow begins to decrease.

So, within the limit imposed by this condition of noninterference, the discharge may be measured by a single head reading. The maximum level to which the downstream water may be allowed to rise is 50 per cent of the upstream head in the case of 3-in., 6-in. and 9-in. flumes, and 70 per cent for flumes from 1 ft. to 8 ft. in width. The loss of head is the difference in level between the water entering and leaving the flume, and this is equal to 50 per cent or 30 per cent of the head on the sill, according to the width of the throat.

In earlier issues of *Water Works and Sewerage* the use of the Parshall flume for the measurement of sewage flows has been described and the formulas given. The selection of the most suitable of flume for any given set of flow conditions, involving consideration of channel width, depth of flow in the channel, loss of head permissible, possible future increases in the flow, and so on, is assisted by the use of charts, the final sizing of the flume being done by calculation from the formula.

The accompanying chart, Fig. 3, has been prepared for sizing flumes of 3-in., 6-in., and 9-in. wide and from 1 ft. to 8 ft. wide (the width referred to is always the throat width). The tables in Bulletin 423 give the flows for various heads for flumes measured in exact feet of throat width from 1 ft. to 8 ft., but for the selection of a flume to suit particular conditions of head and discharge it may be useful to be able to select a size which may be anywhere between 1 ft. and 8 ft. wide.

In selecting a flume for a given duty and set of conditions it will be found that the smaller W is made for a certain discharge the greater will be the head loss, assuming that allowance for the maximum submergence is made in each case. The depth of flow in the channel downstream of the flume and the level of the floor in the chanel may be convenient points to take as the basis for sizing, working back to the water level upstream and the level of the crest or sill. Use of the chart means that a number of different sets of conditions may be tried out quickly to determine the best size of flume for the job in hand.

The range of heads covered by the chart is the same as shown in the various tables in Bulletin 423 and the formulas are those there given for "free flow" conditions, viz.:

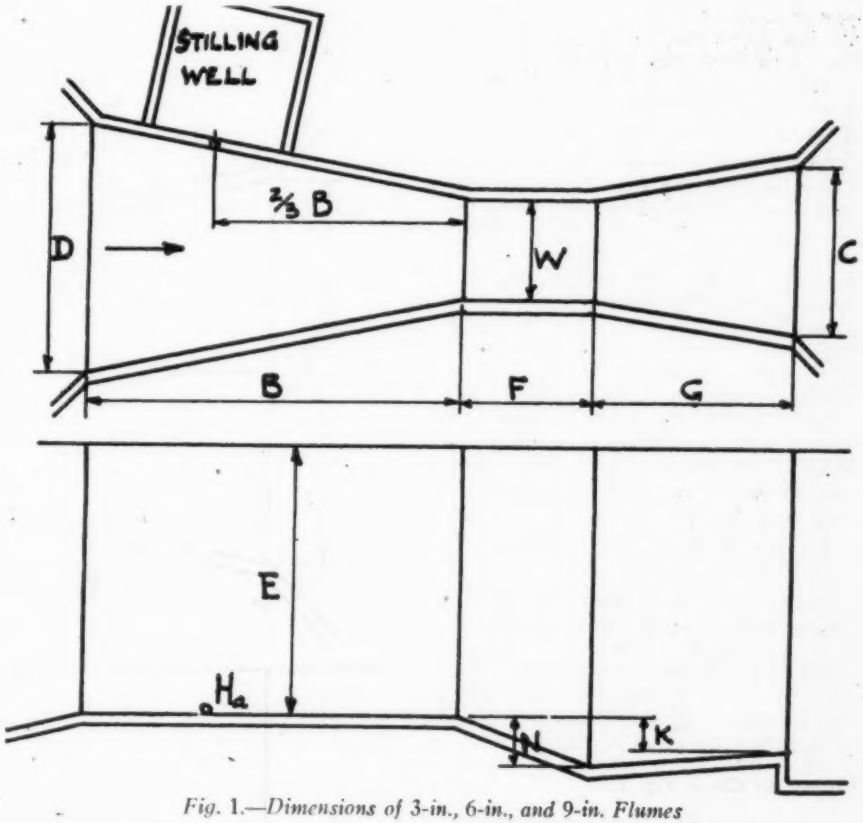

Fig. 1.—Dimensions of 3-in., 6-in., and 9-in. Flumes

TABLE I

Dimensions in 3-in., 6-in., and 9-in. Flumes (See Fig. 1)

W	B	C	D	E	F	G	K	N
in.	ft.-in.	ft.-in.	ft.-in.	ft.-in.	ft.-in.	ft.-in.	in.	in.
3	1-6	7	10-3/16	1-3	6	1-0	1	2¼
6	2-0	1-3½	1-3½	1-6	1-0	2-0	3	4½
9	2-10	1-3	1-10⅝	2-0	1-0	1-6	3	4½

TABLE II

W	1.0	1.25	1.5	1.75	2.0	2.25	2.5
n	1.522	1.5308	1.5381	1.5443	1.5496	1.5544	1.5586
W	3.0	3.25	3.5	3.75	4.0	4.25	4.5
n	1.5660	1.5693	1.5724	1.5752	1.5778	1.5803	1.5826
W	5.0	5.25	5.5	5.75	6.0	6.25	6.5
n	1.5870	1.5890	1.5909	1.5928	1.5945	1.5962	1.5978
W	7.0	7.25	7.5	7.75	8.0		
n	1.6009	1.6204	1.6038	1.6052	1.6065		

	2.75
	1.5625
	4.75
	1.5849
	6.75
	1.5994

Table II gives the value of "n" $= 1.522^{\cdot 026}$ for widths of flume from 1 foot to 8 feet in steps of 3 inches.

"W" is given in feet, and "n" is the value of the index to "H" in the formula, $Q = 4WH^{1.522W^{0.026}}$ which is thus reduced to, $Q = 4WH^{n}$, using second-feet units, so facilitating logarithmic calculation.

For 3 in. flumes—$Q = 0.992Ha^{1.547}$
For 6 in. flumes—$Q = 2.06\ Ha^{1.58}$
For 9 in. flumes—$Q = 3.07\ Ha^{1.63}$
For 1 ft.
to 8 ft. flumes—$Q = 4\ W\ Ha\ 1.1522\ W^{0.026}$

where

Q is the dicharge in cubic feet per second.
W is the width of the throat in feet.
H is the head on the sill in feet.

These formulas, of course, are the same as given in Bulletin 423 but are repeated here in order to make these notes as complete as possible.

It is mentioned in the bulletin that the width of the throat will, generally, lie between one-third and one-half the width of the channel, and this makes a good starting point, but this rule will not apply for extremely wide and shallow, or deep and narrow, channel flows, and will be governed by considerations of head loss, and so on, as mentioned earlier. The Bulletin recommends in considering the loss of head that a submergence of 60 per cent be taken as the practical limit for flumes between 1 ft. and 8 ft. wide so as to allow for possible fluctuations in flow before the conditions affecting the accuracy of measurement by the single head reading would be reached. Similarly the practical limit for 3 in., 6 in. and 9 in. wide flumes might be taken as 40 per cent or 45 per cent submergence.

The head Ha over the sill or crest is read at a point two-thirds the distance back from the crest to the inlet of the converging section, and, if a connection is taken to a stilling well for the float operation of an indicator or recorder, the connection is taken through either side wall, just above the floor, the end of the pipe being flush with the wall face.

Table I and Fig. 1 give the dimensions of the 3-in., 6-in. and 9-in. flumes, those dimensions common to all three sizes being given in the figure.

Dimensions of flumes between 1 ft. and 8 ft. wide are given for exact feet widths in the Bulletin, but for calculating the dimensions "B" and "D" for flumes of any width between these limits the formulas which follow are offered. The throat width "W" is used as the basis of each formula and so when the width has been decided the other dimensions are quickly obtained. "W" is taken in inches and the other dimensions are derived in inches. The results compare very closely with the dimensions given in the Bulletin for widths of even feet, and so may be used for intermediate widths.

B = 0.49 W + 47"
C = W + 12" (See Table I. Bull. 423)
D = 1.196 W + 18.84"

Thus, for a 30-in. flume: B = 0.49 × 30 in. + 47 in. = 61.7 in.; C = 30 + 12 = 42 in., and D = 1.196 × 30 + 18.84 in. = 54.72 in. Position of dimensions "W," "B," "C," and "D," and dimensions which are common to all sizes between 1 ft. and 8 ft. flumes are given in Fig. 2.

Using the Chart: Fig. 3:

The use of the chart is illustrated by the lines A.B.C. and D.E.F. which cross the scales. A.B.C. shows that a flume 24 in. wide will pass 8.0 cu. ft. per second or 5.17 mgd. (U. S.) when Ha is 12 in. Line D.E.F. is used to show the flow through a 9-in. flume when the head is 6 in. This equals 1.06 cu. ft. per second or 0.685 mgd.

Similarly, for 3 and 6-in. flumes, the flow is obtained by using the appropriate points for the width and the corresponding scale for the head. Thus, it will be clear that one scale is used for the flows for all sizes with separate scales for the head for 1 ft. to 8 ft., 3, 6 and 9-in. widths, respectively. A scale of widths is given for 1 ft. to 8 ft. with points for 3, 6 and 9-in. widths, no intermediates being given for these, each of which is set out according to the formula given for that size.

In the stilling well, shown in Figs. 1 and 2, a scale may be placed against the wall, having its zero at the level of the flume crest. This may be calibrated from the chart or from the calculated rate from the formula, depending on the degree of accuracy required. A mechanical indicator operated by a float in the well may be mounted above the well to give a continuous indication or record of the flow.

The location of the measuring flume in the channel is a matter requiring some consideration. The Bulletin suggests that a certain length of straight channel should precede the flume but is not specific about this. The approach should be arranged so as to give conditions free from turbulence.

The velocity of the water in the channel leading to the flume should be less than the critical velocity, and, with this limitation, a variation of as much as 300 per cent in the velocity of approach was found to have no effect on the discharge. Where the depth in the approach channel is low and the velocity high, the selection of a flume size can be made which will increase the head, and therefore the depth in the approach channel, so decreasing the approach velocity to a suitable figure.

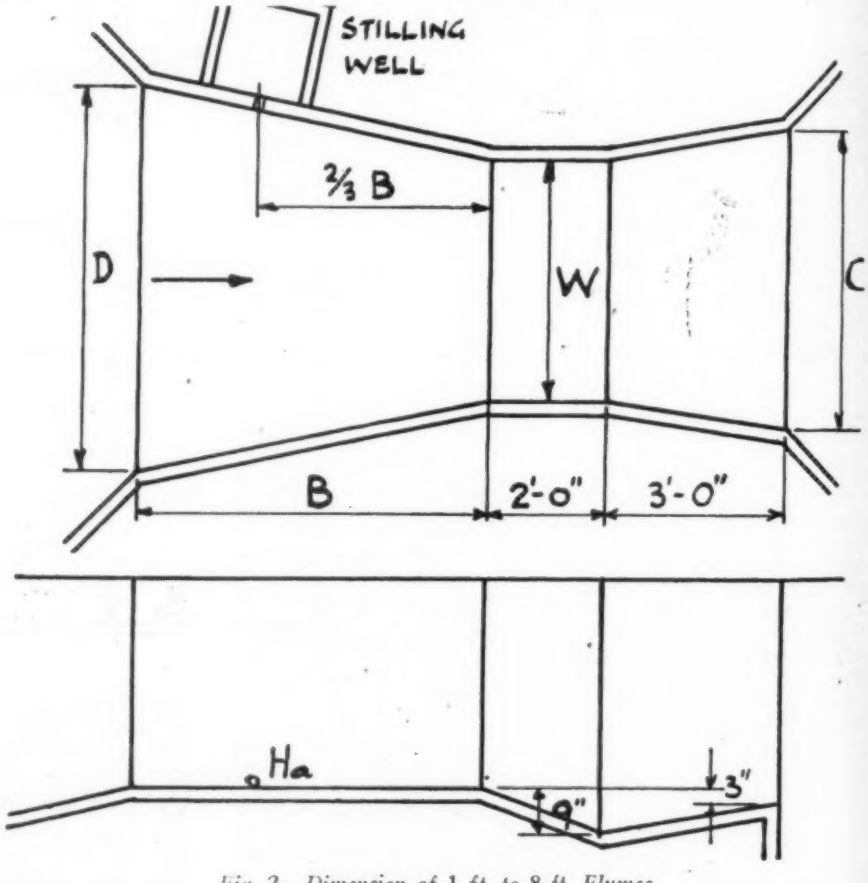

Fig. 2.—Dimension of 1 ft. to 8 ft. Flumes
(See Formulas for B, C, and D)

Larger Flumes—Dimensions of wider flumes, that is, of widths greater than 8 ft., are not calculated from the formula as given above. Figures for flumes from 10 to 50 ft. in width are given in Bulletin 386 of the Bureau, the largest having a capacity up to 3,000 cu. ft. per second.

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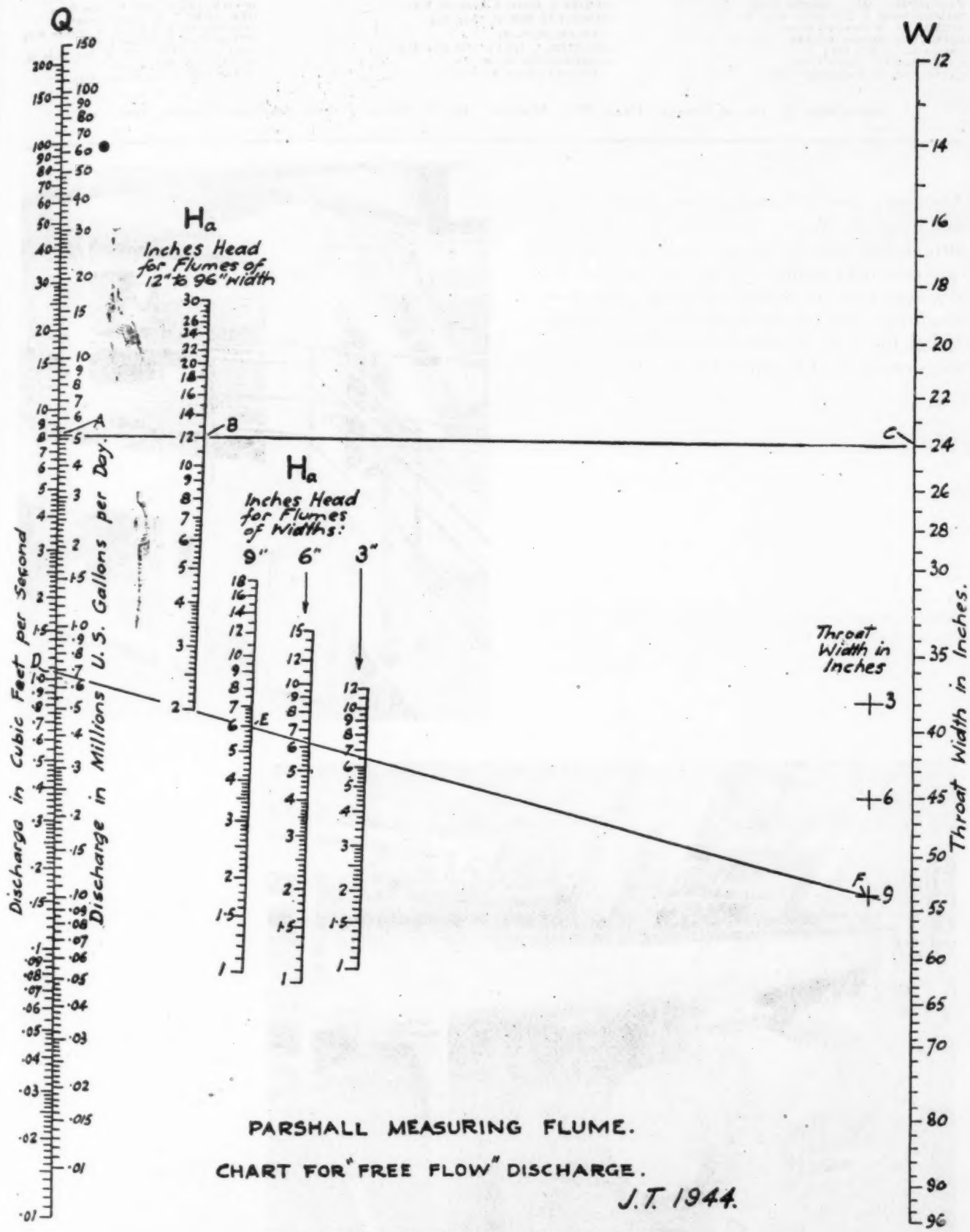

Fig. 3.—Chart for Free Flow Discharge of Parshall Flume

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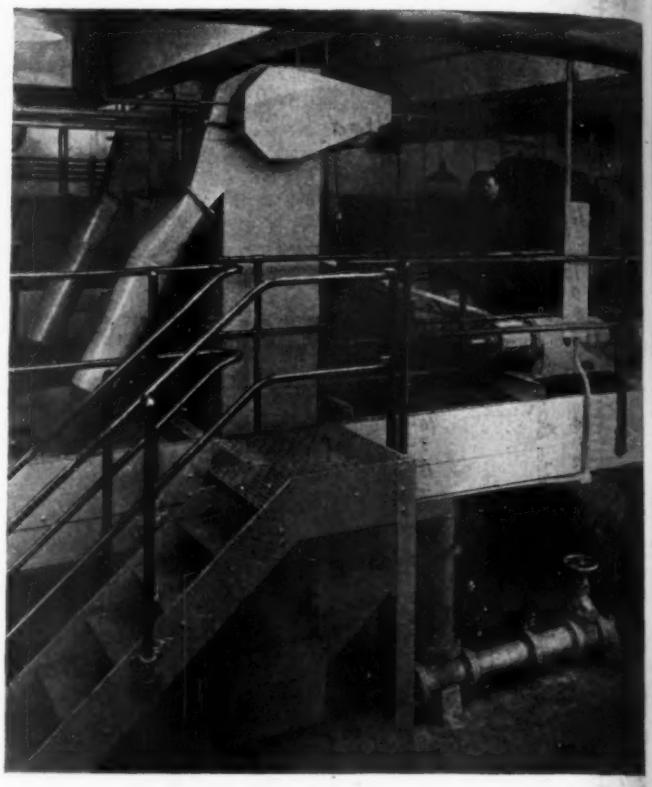
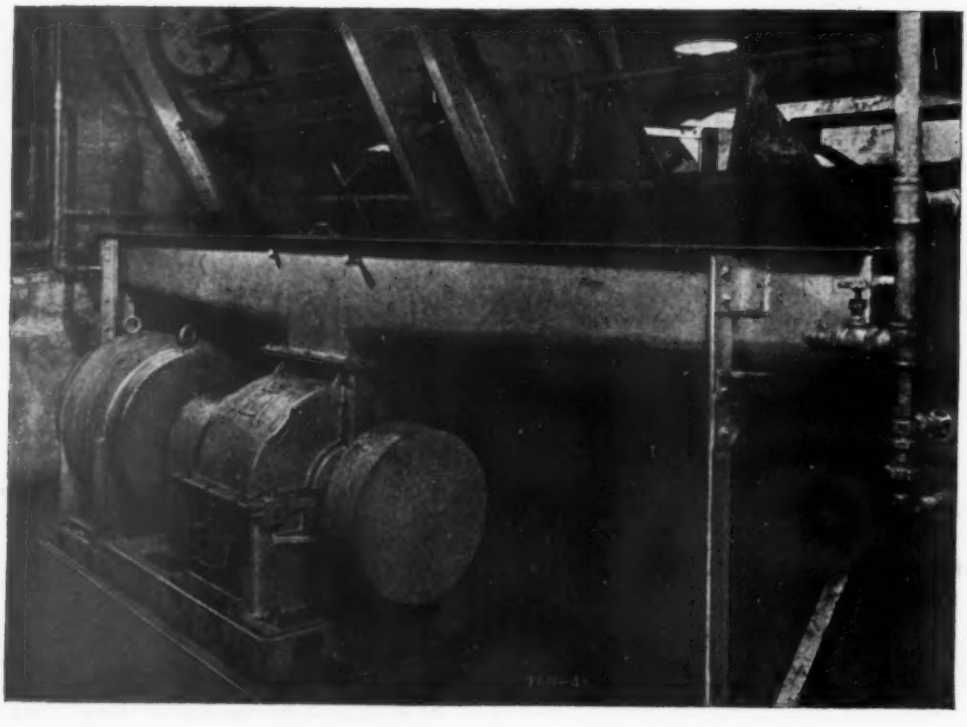
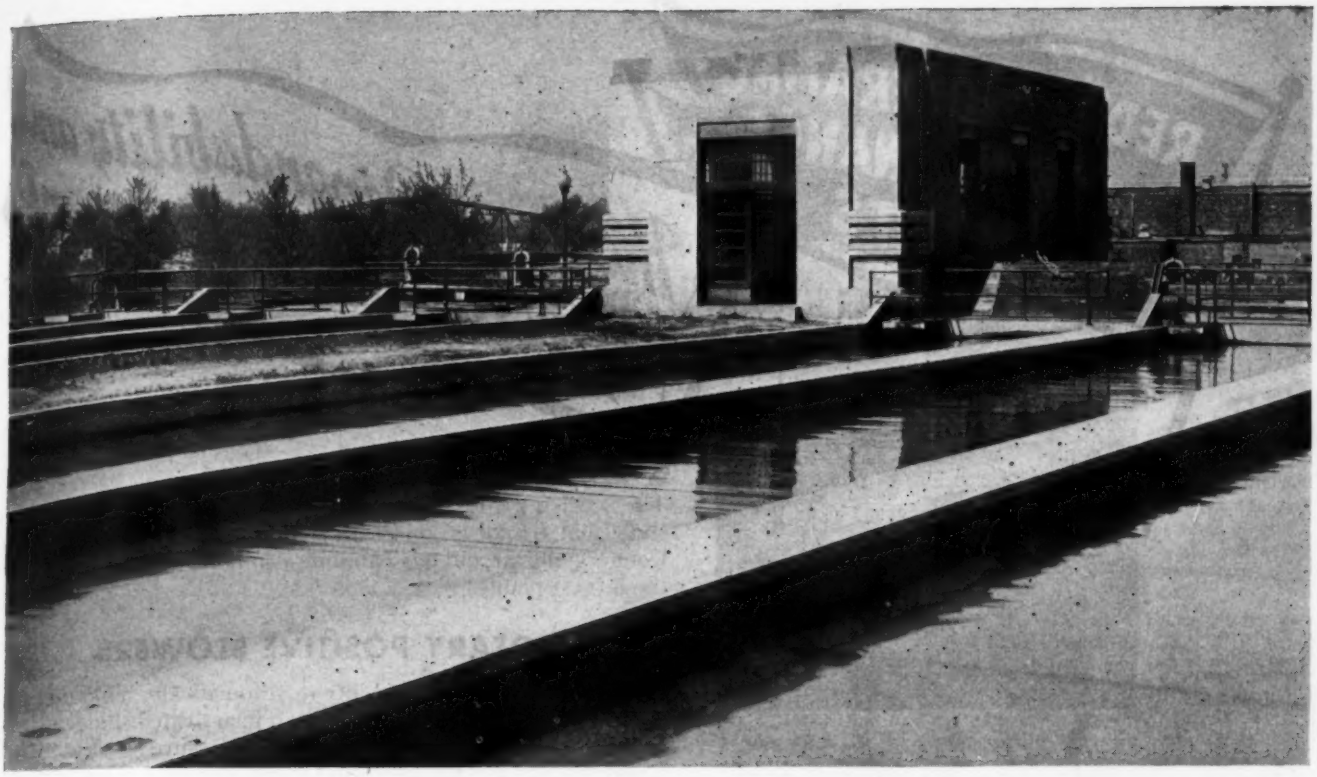


At right—Two No. 4 JIGRIT Washers at the Tallman's Island Sewage Treatment Works, Department of Public Works, New York City. (Patented).

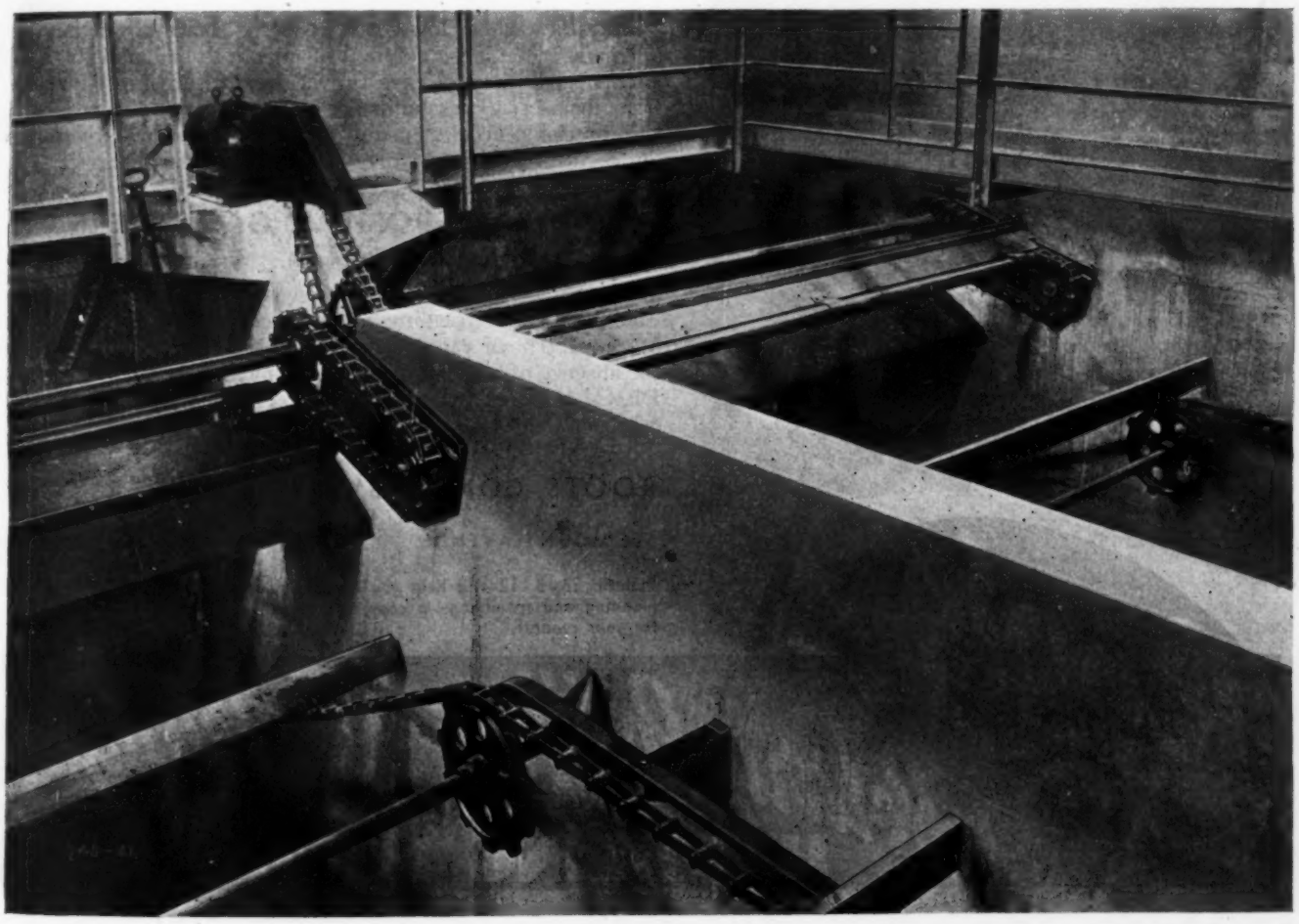


Two Jeffrey Mechanically Cleaned Screens discharging into a Jeffrey Screenings Grinder at the Hammond, Indiana, Sewage Treatment Works.



Above—Primary Settling Tanks with individual motor drives at the Hammond, Indiana, Sewage Treatment Works.

Below—Automatic Skimmers removing fat from skimming basins in a Packing Plant. Entire cost of plant and equipment paid for out of sale of recovered grease in about six months.



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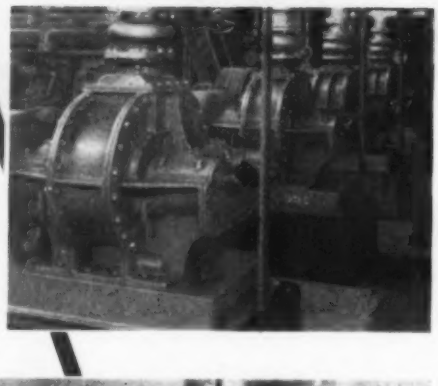
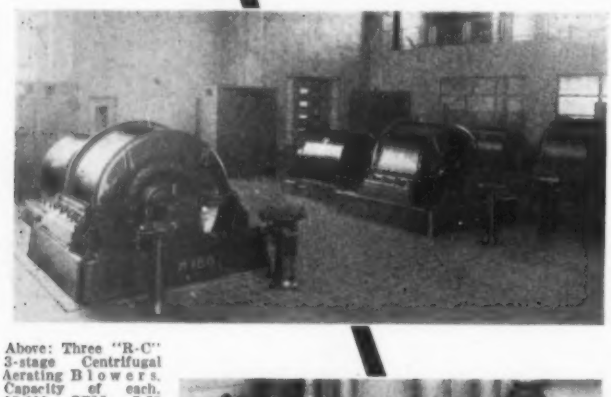
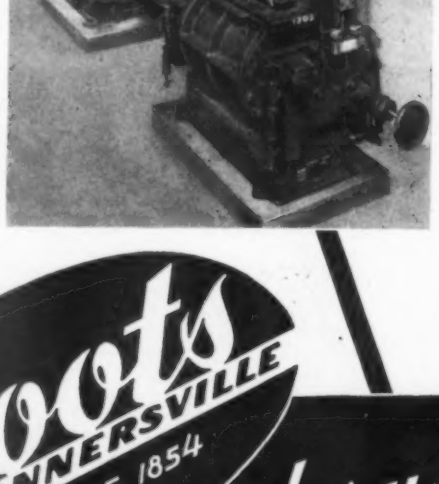


Four "R-C" Aerating Blowers — two driven by electric motors and two by gas engines. Capacity of each, 1,800 CFM, 7.5 lbs. pressure.



Above: Three "R-C" 3-stage Centrifugal Aerating Blowers. Capacity of each, 15,000 CFM, 7.75 lbs. pressure. Driven by electric motors.



This photo shows two "R-C" Meters for measuring sludge gas. Capacity of each, 10,500 CFHr.

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OPERATING FUNDAMENTALS OF THE ACTIVATED SLUDGE PROCESS

T. R. HASELTINE, Supt. Sewage Treatment
Butler and Grove City, Pa.

THE properties of activated sludge which are most important to the plant operator are, first, its clarifying or absorptive powers, and, second, its oxidizing power.

When activated sludge is mixed with sewage it absorbs the finely divided suspended matter, the colloids, and probably much material in true solution in or on its floc surfaces. If the sludge is then allowed to settle out, the supernatant liquor will be clear instead of cloudy. This clarification action is very rapid and is probably completed in 10 to 30 minutes.

The oxidizing power of activated sludge is generally assumed to be entirely due to biological action. Although its oxidizing action may be some 60 to 130 times faster than the normal oxidizing rates, as measured by the standard B.O.D. test, it is still much slower than adsorption or clarification.[1] The highest rate of oxidation usually occurs when the sludge first comes in contact with the sewage. It then falls off gradually for the next two to five hours, after which it continues at a more or less uniform rate for considerable periods of time.

In any properly functioning plant there is a balance between these two properties. Almost all of the troubles encountered with the activated sludge process may be traced to a lack of proper balance. For example, if biological oxidation proceeds more rapidly than adsorption, the sludge floc become very small and compact. This dense floc does not produce a sparkling clear effluent although nitrification may be very high. Furthermore, some of the floc is apparently broken up into minute particles which do not settle in the final clarifiers, even though the main body of the sludge settles very rapidly. On the other hand, if oxidation lags behind adsorption, the sludge floc will become so light that it will not settle in the final tanks and the sludge will lose much of its clarifying power. Since adsorption is very rapid and almost automatic, the operator's problem is to regulate the rate of biological oxidation so that it just keeps pace with adsorption under the aeration periods prevailing in his particular plant.

There are several conditions under which oxidation will progress more rapidly than adsorption. Probably the most common is over aeration. It is encountered in plants having excessive blower capacity in a few large constant speed machines. It is best overcome by carrying more sludge in the aeration tanks. A second, but less common, cause of over oxidation is too long an aeration period. The best corrective is to bypass part of the aeration tanks. If that cannot be done, then increase the amount of sludge in the mixed liquor. A third cause of over oxidation may be lack of sufficient "food" in the sewage. The writer encountered such a condition at Grove City during the early spring. At such times our sewage flow is increased by ground water to four or five times its dry weather volume. Most of the excess flow has to be bypassed and hence only one-third to one-fourth as much organic matter enters the aerators as normally. We have found that the admittance (after liming) of digester supernatant to the aerators was quite helpful at that season.

Causes of Oxidation Lag

There are at least six possible causes of oxidation lagging behind adsorption, as follows:

(1) *Inadequate Oxygen Supply:* In any aeration tank (mechanical or diffused air) we have two opposing forces, one, the aerator device injecting air into the mixed liquor, and two, the biological organisms using up oxygen in their life processes. Dissolved oxygen determinations on the mixed liquor give a measure of the excess of the oxygen supply over the oxygen consumption. It is absolutely essential that the rate of supply be at least equal to the rate of consumption, but there is nothing to indicate that any great excess is beneficial.[2] If there is no dissolved oxygen in parts of the aeration tanks then either the oxygen supply must be increased by using more air, or the rate of oxygen consumption must be cut down by reducing the amount of sludge or sewage in the mixed liquor. Naturally sludge reduction is the most general practice.

(2) *Germicidal Wastes:* Since oxidation is entirely biological it is evident that germicidal wastes will stop or retard it. If the germicidal action is due to excessive acidity or alkalinity neutralization with lime or acid will eliminate it. (The optimum pH for biological oxidation is 7.0 to 7.5 although there is little retardation at pH 6.4 to 8.0.[4] If it is due to phenolic compounds or other toxic substances, the only certain remedy is to exclude them from the sewers. In some cases, however, where the concentration of the poison is quite uniform and not too high it may be possible for the sludge organisms to become accustomed to it.

(3) *Excessive Carbon Dioxide:* Carbon dioxide is one of the principal end products of biological oxidation[3,4] and excessive amounts of it are known to be toxic to bacterial activity. Sewage already contains relatively large amounts of CO_2. Although aeration is an efficient means of removing carbon dioxide the rate of its production during the activated sludge process is so great that the net reduction due to aeration may be slight. In such cases it is quite possible that the rate of oxidation is limited by the CO_2 content of the mixed liquor. When such conditions prevail it is logical to apply lime to the inlets of the aeration tanks.[4] Either one of two general schemes may be followed: (a) daily applications of 50 to 300 lbs. of lime per M.G. of daily flow applied in one to four "shots" during hours of peak sewage flow, or (b) continuous lime applications at rates of 300 to 500 ppm. until such time as the pH at the outlet of the aerators approaches 8.0. The best way to tell whether or not excessive CO_2 is causing trouble is to try the lime treatment. It is fortunate that this treatment can do no harm so long as the pH at the outlet of the aerators does not exceed 8.8, whether or not it does any good.

(4) *Septic Sewage or Sludge:* Septic action not only increases the carbon dioxide but produces other products that retard biological oxidation. Avoid sludge accumulations in sewers, channels, primary or final clarifiers. The return of large volumes of poor quality digester overflow liquor to primary tanks may cause the entire sewage flow to become septic. Frequent sewer flushing may be helpful. Prechlorination at various points along the collection system may be even more helpful. Partial chlorination of the return activated sludge has proved beneficial at some plants but chlorine is a powerful germicide and particular care is required to avoid over-chlorination of the sludge which might destroy its oxidizing power.

(5) *Excessive Grease Content of the Sludge:* If the grease content of the sludge is excessive the sludge particles become coated with a film of grease thus preventing intimate contact with oxygen, even though tests show an abundance of dissolved oxygen in the mixed liquor, hence oxidation is greatly retarded. Wiest's[6] work indicates that the activated sludge process functions satisfactorily when the grease content of the sludge is 5 to 7 per cent, but gives considerable trouble when the grease content is around 20 per cent. The writer's experience indicates that 13 per cent grease in the sludge makes for difficult operation while 30 per cent grease causes the sludge to lose its clarifying power and a very inferior effluent results. If the grease content of the sludge is generally excessive then some means of further removing grease from the incoming sewage is indicated. But where the trouble is caused only by periodic shots of mineral oil the writer has found a 25 per cent increase in air for a day following such shots to be helpful.

(6) *Inadequate Aeration Period:* Even under ideal conditions biological oxidation is much slower than adsorption and, hence, there is some minimum aeration period required below which the process will not function. Usually there is nothing the operator can do but bypass part of the sewage flow and ask for more aeration tanks. In some cases, however, short circuiting in diffused air plants has been a factor that could be corrected by proper baffling. Current meter readings at various points may be helpful in designing or locating baffles. In other cases it has been possible to delay major extensions by utilizing part of the aeration tanks for sludge reaeration, thus lengthening the available time for biological oxidation.

Since both the quantity and strength of the sewage varies from hour to hour and day to day, it might be asked, how is the operator to maintain a constant balance between adsorption and oxidation at all times? He can not! In the normal plant oxidation probably falls behind adsorption during the high flow of strong daytime sewage and catches up during the low flow of

weaker night sewage. In some plants it is even possible to observe a gradual deterioration of the sludge through the week with recovery over Sundays. It must always be kept in mind that it is only prolonged periods of excessive adsorption that cause serious sludge deterioration, and that several days of excessive oxidation are required for its recovery. The closer the balance is maintained the lower will be the power costs, but the higher will be the laboratory and attendance costs. Therefore more laboratory work is justified in large plants than in small, but some is required in all.

Sewage Input vs. Air Input, and the D. O. Test

Since most if not all of the oxidation occurs in, or on, the sludge floc, it should be evident that most of the oxygen is consumed by the sludge. Therefore, it is a serious mistake to attempt to regulate the air input in proportion to the sewage flow. Dissolved oxygen determinations throughout the aeration tanks are the best criterion known for air regulation. If the air is to be varied throughout the day then these tests should be made at various hours throughout the day. If a constant rate of aeration is to be used then the tests should be made at whatever time the dissolved oxygen is at a minimum; this will usually be found a few hours *after* receipt of the peak sewage flow. Samples should be collected from various points between the inlet and the outlet of the aerators. Unfortunately the dissolved oxygen determination, the most important of all operating control tests, can not be made directly on the mixed liquor because of interference from the sludge floc. The accurate determination is extremely difficult and requires special equipment,[7] however tests for routine plant control may be made on samples of supernatant liquor siphoned off from larger samples of mixed liquor collected from the aerators. At Salinas, California,[8] the writer collected 2 liter samples from the tanks and allowed them to stand until sufficient clear water could be siphoned off to fill the small D.O. bottles. Ordinarily 5 to 15 minutes standing sufficed although at times of severe bulking as much as 40 minutes was required. That procedure is open to the objection that the sludge consumes some oxygen during the sedimentation period. However, on several occasions we siphoned off a second sample an hour or two after taking the first one and repeated the D.O. determinations; the decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small. Theroux, Eldridge and Mallman[9] recommended the addition of 10 ml. of 10 per cent copper sulphate solution to the 2 liter samples of mixed liquor. The copper sulfate acts as a coagulant, speeding up sedimentation, and at the same time halts biological oxygen consumption. Theoretically, at least, this method is open to the objection that the copper sulfate tends to react with the potassium iodide added later liberating iodine and thus giving results that are too high. Heukelekian uses about half as much 10 per cent sulfuric acid in place of the copper sulfate. The writer has tried all three methods simultaneously at Grove City on several occasions and found little or no practical difference. We use copper sulfate in our routine work.

Regardless of the method used to separate out the sludge floc the Rideal-Stewart modification of the Winkler method should always be used for determining the oxygen in the small, siphoned samples because of the possible presence of nitrites in the liquor, see "Standard Methods."[23]

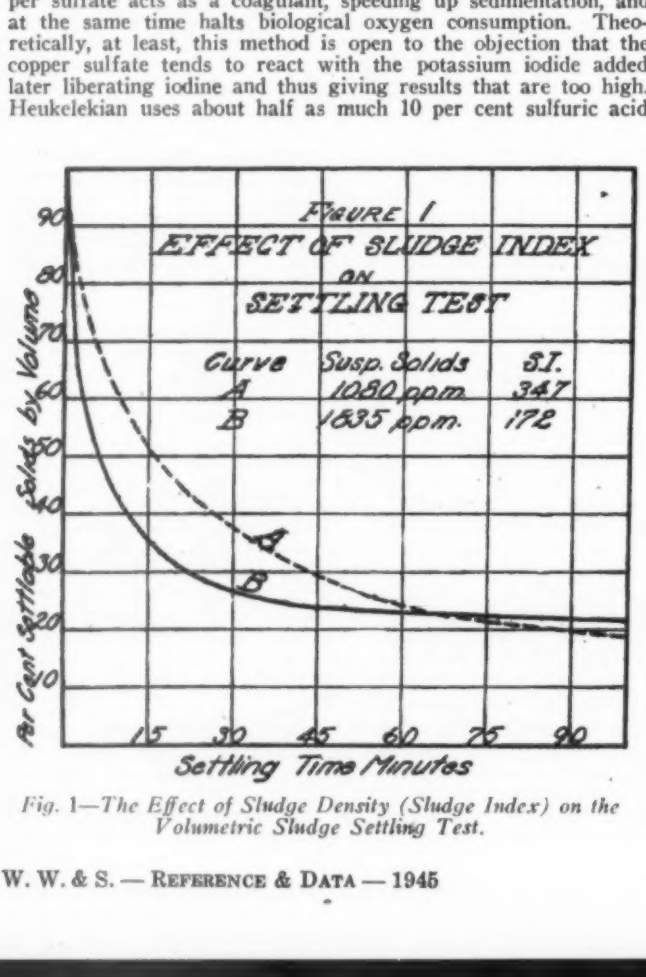

Fig. 1—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Measuring Sludge in Mixed Liquor

We have mentioned increasing or decreasing the amount of sludge in the aerators as a means of controlling the oxydation-adsorption balance. This leads us to the second most important control test, namely, some means of measuring the amount of sludge in the mixed liquor. By amount of sludge we mean *weight* of sludge solids. No universal rule can be given for determining the proper amount. Perhaps 600 to 1500 ppm. of suspended solids in the mixed liquor would cover most mechanical aerators while 1200 to 3000 would cover most compressed air plants. The higher the sludge content of the mixed liquor the faster will adsorption and oxidation progress, but the greater will be the power requirements. If the aeration period is short an increased sludge content will give a higher degree of treatment, but if an adequate aeration period is available almost as good purification can be obtained with a low sludge content and a considerable saving in power may be realized. With a low sludge content organic matter adsorption per unit weight of sludge is very high and hence a very high rate of biological oxidation must be maintained. Therefore, if the sludge content is low, there is more danger of a plant being upset by sudden shots of strong sewage or organic trade wastes.

Standard suspended solids determinations are the only accurate means of finding the actual weight of sludge solids in the mixed liquor. Unfortunately the test requires considerable time and, for small plants, expensive equipment. In spite of these handicaps the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day. The time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day—usually 8 or 9 a.m. will be the most satisfactory time. The writer has followed this practice at Salinas,[8] Topeka[16] and Grove City. We governed the daily amount of activated sludge, wasted almost entirely by the results of these determinations. This procedure does *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably a minimum at the time the peak flow started coming in and at a maximum in the evening when the sewage flow drops off. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant. If it is desired to hold the solid content of the aerators constant throughout the day then one of the approximate "short-cut" methods of solid determination (to be described later) may be used as frequently as desired, but the standard suspended solids test should be made daily as a check on the short-cut procedure. After considerable experimentation the writer has concluded that the saving in power made possible by hourly checks of the solid content of the aerators was not sufficient to justify the time consumed in checking, but such a conclusion can apply only to the plants with which he was connected. Anderson, employing a centrifugal estimation, has found the opposite to be the case at Rockville Center.[11, 12, 13]

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas[8] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 ppm. under varying sludge conditions; at Grove City the range is 200 to 500 ppm.

Because of the time required for suspended solids determinations various short-cuts have been used. The simplest are the settling tests and these were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of that time. In the early days it was usually customary to carry a volume of about 20 per cent sludge, after 30 minute standing of the mixed liquor. The test is still used and is quite helpful so long as its limitations are

kept in mind. Various standing times are used, ranging from 10 minutes to 1 hour or even longer.

The Sludge Index

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of suspended solids in the sample soon showed that no such relationship existed unless the sludge index[9] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes"; it is computed by multiplying the per cent sludge by volume after 30 minutes standing by 10,000 and dividing that product by the parts per million of suspended solids by weight in the same or a similar sample of mixed liquor. The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and, hence, the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. In general the settling test alone cannot be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate determinations.

The Centrifuge Test

Another short-cut is the centrifugal test. This test consists of collecting samples of mixed liquor or sludge in 15 ml. centrifuge tubes and "spinning" them for a given short time (2 to 10 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed.

The writer first heard of this test being used at the Indianapolis plant in 1928. Like the settling test, it is, at best, a volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. First, it is extremely rapid, and, second, it compacts the solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. The writer has used a 2 minutes spinning period at 2600 r.p.m. at Salinas and Grove City. At both plants we found that the results of this test were greatly influenced by the sludge index, see Figure 3. Setter[10] used a 10 minute period at the same speed and got fair correlation with the suspended solids test so long as the suspended solids exceeded 1000 ppm.; at lower solids concentrations the volume of sediment was too small to permit satisfactory readings. Anderson[13, 11, 12] used a 5 minute period at 1800 r.p.m. at Rockville Center and considers the test very satisfactory although he gives no data to correlate it with suspended solids determinations. If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index at daily to weekly periods and from that determination and the graph he can select the desirable centrifugal test results for more frequent determinations.

In addition to determining the amount of sludge being carried in the aerators it is desirable to know something of its condition. The sludge index, as previously described, is valuable in this respect. Color, odor, and floc structure are also valuable. Periodic microscopical examinations are useful. After a little experience these tests, or observations, will usually be found adequate for most plants. In some cases the volatile content or dissolved solids content of the sludge may be found helpful.[8] Still better tests required special equipment such as the Odeeometer,[14] Oxy-Utiometer,[15] etc.

Tapered Aeration vs. Delayed Loadings

It was previously stated that the rate of oxidation was usually highest when the sludge first comes in contact with the sewage and that afterwards it falls off gradually. If the air is supplied in just sufficient amounts to maintain a minimum dissolved oxygen content at all points in the tanks it will be found that considerably more air is used at their inlet ends than is used at their outlets. This method is known as *tapered aeration*. Since the rates of adsorption and oxidation increase with increased amounts of sludge, tapered aeration is more necessary when a high sludge content is carried. The rate of oxygenation is limited for any aeration device, but is generally lower for mechanical aerators than for compressed air plants,[17] hence the former usually carry less sludge and frequently provide longer aeration periods. At the Tallman's Island[18] plant provision is made for adding sewage or return sludge at several different points along the aeration tanks, thereby avoiding the necessity of using such high aeration rates at their inlets. In small plants it is possible to reduce the necessity for tapered aeration by returning a large volume of very dilute sludge. Experience has taught many operators that this practice is a good one for small plants in particular. The excess water reduces the oxygen demand of the mixed liquor at the aerator inlets and forces the sludge along the aeration tanks faster, thereby reducing the air requirements at the inlet end and increasing it further along the tanks.

Importance of Prompt Sludge Recirculation

It used to be considered good practice to carry a considerable depth of sludge in the final clarifiers in order to get as high a solid content, and hence as low a volume of return sludge as possible. Studies[19] have shown that the oxygen demand of such sludge is frequently so high that it is almost impossible to satisfy it by any aerating device. It has also been found[20] that the activity of the sludge was greatly impaired by even comparatively short concentration periods in the clarifiers and that the fresher the sludge the greater was its purifying power; the effect being most noticeable at plants having a short aeration period. Therefore, the rate of withdrawal from final tanks should be such as to remove the sludge as quickly as possible. In large plants where the cost of pumping excess water may exceed attendance, or in plants using sludge reaeration, it is wise to make frequent sludge soundings and to keep the rate of withdrawal at a minimum consistent with rapid sludge removal. In small plants that do not have sludge reaeration this extra attendance is not justified and a very high, constant, rate of sludge withdrawal can be used throughout the 24 hours. When the plant is treating a strong sewage the daily sludge withdrawal may be actually equal to the sewage flow with no ill results and, possibly, some benefit. (At first it might appear that such an increase in volume of sludge return would unduly shorten the aeration period; however, it may be shown mathematically that increasing the rate of return from 20 per cent to 50 per cent (equal sludge and sewage volume) cuts the nominal aeration period only 10 per cent because so much of the liquor in consequence passes through the aerators more than once.)

Most plants are not designed for sludge reaeration. If reaeration is used it is desirable to keep the rate of sludge withdrawal from the final tanks at a minimum, consistent with rapid sludge removal, in order to have the longest reaeration period, *providing it is possible to maintain some dissolved oxygen at all points in the reaeration tank.* If that can not be done then the rate of withdrawal *must* be increased so as to reduce the oxygen demand of the reaerating sludge.

Sludge Concentration Important

To intelligently divide the sludge withdrawal between return and waste it is necessary to make daily suspended solids tests on the mixed liquor, as previously discussed. If these results are

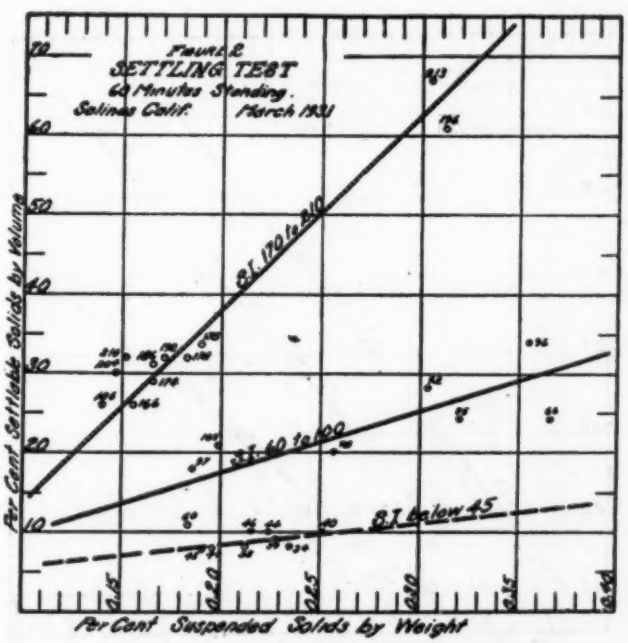
SETTLING TEST
60 Minutes Standing.
Salinas Calif. March 1931
S.I. 170 to 210
S.I. 60 to 100
S.I. below 45
Per Cent Settleable Solids by Volume
Per Cent Suspended Solids by Weight

Fig. 2—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

below the amount of sludge desired the amount going to waste should be decreased and vice-versa. Waste activated sludge should always be concentrated before introducing it into sludge digestion tanks. At most plants the only means of concentration provided is the introduction of waste activated sludge into the primary settlers. It has been the writer's experience that where this method is used better concentrations of primary sludge are obtained by wasting continuously over the 24 hours at a low rate than are obtained by wasting at a high rate for a shorter time. This method of wasting excess activated sludge has many disadvantages,[21] particularly when the sludge is bulked. A better, though less common method entails the use of a separate tank, termed a sludge thickener, and the use of chlorine.[22, 23] Where a thickener is provided best results are obtained by feeding it with mixed liquor direct from the aeration tanks instead of with sludge withdrawn from the final clarifiers. The clear, chlorinated supernatant from the thickener may be discharged to the incoming raw sewage, the return activated sludge or the final effluent. Either of the first two are preferable because of its beneficial action in overcoming septicity.

Troubles

Now just a few words concerning troubles. Sludge bulking is probably the most common trouble encountered with the activated sludge process. The term "bulking" has been used by some to cover the condition of sludge pouring over the weirs of final clarifiers, but the writer considers that an improper use of the term. A bulked sludge is simply a sludge that, after a given settling period, occupies a greater volume than would a normal sludge containing the same amount of suspended matter by weight. Bulking is best measured by the sludge index[9] as previously described. Whether or not a bulked sludge will pour over the weirs of final clarifiers depends, primarily, upon the design of those tanks. The more generous their design the higher can the sludge index become before the effluent is fouled.

It was previously stated that when oxidation lagged behind adsorption the sludge floc became so light that it would not settle properly, in other words, the sludge bulks. We have given six possible causes of oxidation lagging behind adsorption and suggested means of overcoming them. Any one of those six will cause bulking if not corrected. Certain microscopic, filamentous, growths will cause, or increase, bulking. Sphaerotilus is far the most common organism. Even though the sludge is constantly seeded with these organisms they do not flourish in the sludge if oxidation is keeping pace with adsorption, but if oxidation lags behind adsorption the sludge may become an ideal habitat for profuse growths. Correct the oxidation-adsorption balance and the number of Sphaerotilus will greatly diminish. Other filaments than Sphaerotilus may cause bulking, notably Cladothrix and Leptothrix, but their occurrence is so rare as to warrant no discussion here.

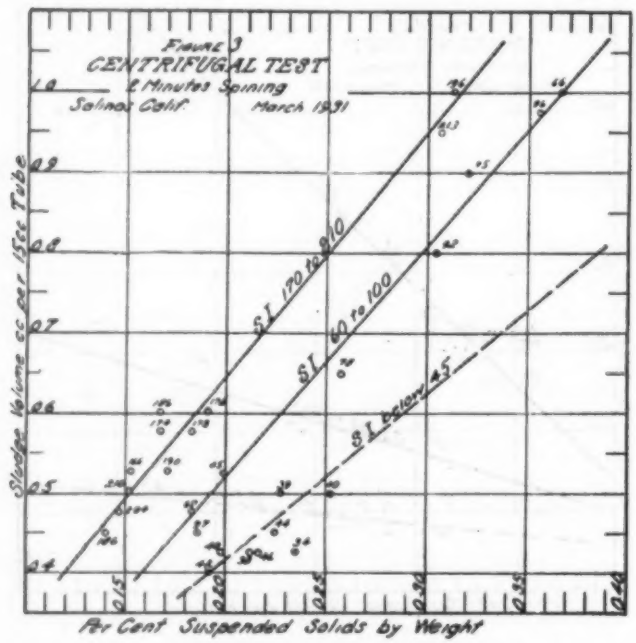

Fig. 3—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

Bulking is not the only cause of excessive amounts of sludge passing out with the final effluent, although it is the most common one. There are two other causes. One is simply insufficient sludge withdrawal, the other is "sludge rising." Rising sludge is most commonly encountered in plants treating sewage high in nitrogenous matter (notably meat packing wastes) where nitrification is quite high. The sludge will settle rapidly in tanks or graduates, but will rise again in from 20 to 90 minutes. The sludge is lifted by accumulations of nitrogen gas. At some plants[24] it has been overcome by keeping the dissolved oxygen in the aerators very low; at others[16] it has been found helpful to increase the amount of sludge carried in the aerators.

Digester overflow liquor has caused considerable trouble at several activated sludge plants, among them Grove City. At most plants it is common practice to return digester overflow to the raw sewage, and, in a properly proportioned plant, the liquor will cause little or no difficulty providing its solid content does not exceed 0.2 per cent. If the overflow contains more than 0.5 per cent solids it turns primary clarifiers septic and covers them with gas-buoyed sludge. Under such conditions their effluent is very difficult to treat by the activated sludge process. At Grove City we have an overflow averaging well over 1.0 per cent solids. We add lime to it and turn it directly into the aeration tanks. The proper lime dosage, in our case, seems to be about 1 pound of lime to each 10 cubic feet of liquor. The liquor turns the aerators very dark, detracts from the appearance of the effluent, and unquestionably puts a tremendous burden upon the activated sludge process. However, we have been able to treat most of the liquor in this way although it seriously upset the plant when we attempted to return it to the raw sewage.

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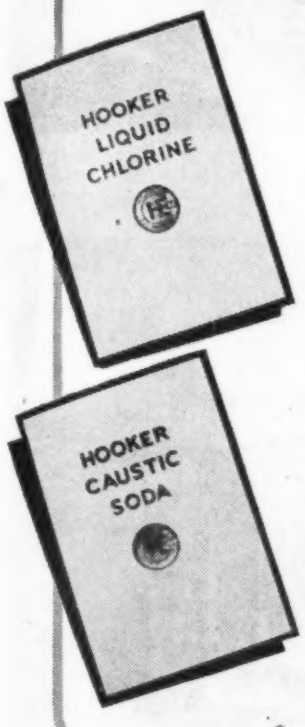

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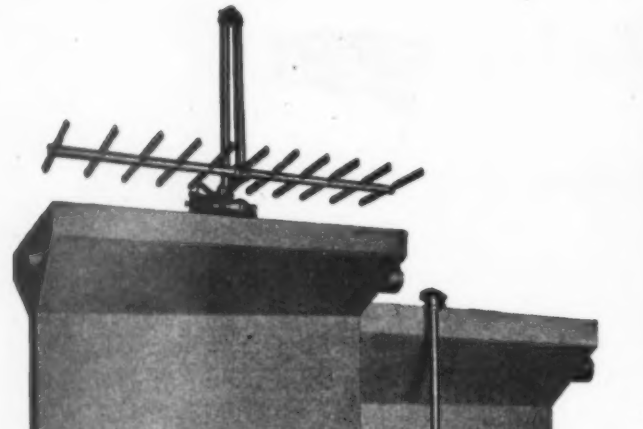

Fig. 2914—Swing Diffusers
Controlled aeration for the Activated Sludge Process. For towns of 4,000 and up. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

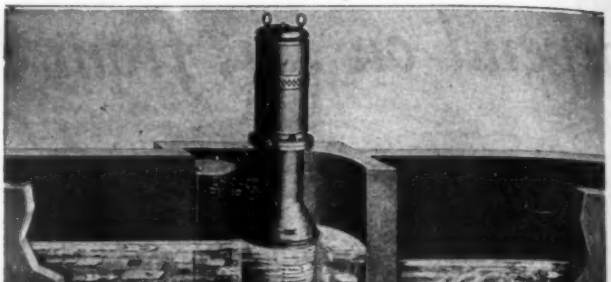

Fig. 2202—Comminutor
Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.

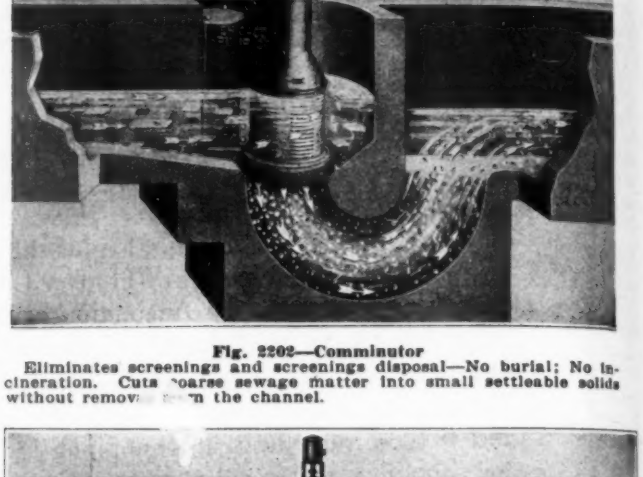

Fig. 2349 (right)—Combination Aerator-Clarifier
providing complete treatment of sewage without odor nuisance and with minimum manual operation. Ideal for housing projects, small camps, institutions and small towns. Over 100 units operating successfully. Ask for Bulletin 128-K.

Fig. 2504—Vertical Open-Shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

Fig. 1860—Scru-Peller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

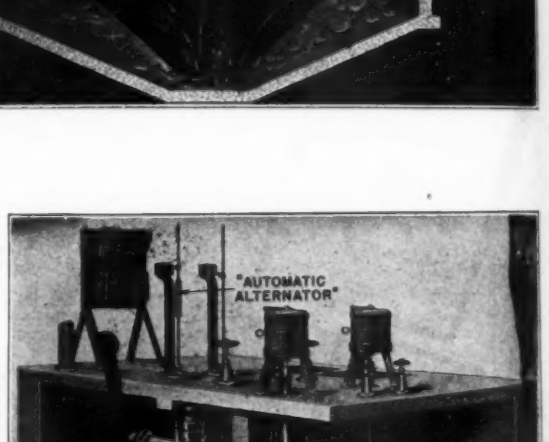

Fig. 2036—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

EXPERIENCE IN MECHANICAL ACTIVATED SLUDGE PLANT OPERATION*

By DOUGLAS E. DREIER
Senior Sanitary Engr., Illinois Dept. of Pub. Health, Springfield

CONTINUING the program of "The Operator's Corner" in presenting studies of actual operation procedures in fundamental sewage treatment processes, this article reviews control practices in mechanical activated sludge plants. It is largely based on data and comments obtained from 27 superintendents, engineers, chemists or operators of 29 representative plants through detailed questionnaires and through supplementary correspondence.

An effort was made to obtain an even distribution of returns from plants utilizing the three most common types of mechanical aerators and, while complete success in that regard was not achieved, it is believed that adequate distribution was obtained. It is not the purpose of this review to discuss and compare the relative merits of mechanical aeration equipment of the several types. Grateful acknowledgment is given the complete co-operation of the following contributors:

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A wide variation in capacity, loading and design is indicated in the general data for the plants contributing, as tabulated in Table I. The loading data tabulated in the ninth column of the table were calculated from the information submitted. While the data in that column are of general interest in indicating the relative degree of loading at the various plants, they should not be interpreted too broadly for the reason that some of the B.O.D. data utilized in the calculations may have been obtained from grab samples while other data were obtained from composite samples.

Placing a Plant in Operation

Before going into the detailed operation control procedures, it might be well to discuss first the general method of placing a plant in operation. In building up a healthy, well conditioned activated sludge it is important that certain fundamental factors be considered and followed.

The organisms which go into the building of an activated sludge are all present in the sewage, but in order that those organisms may become acclimated and cultivated it is important that the aeration mixture contain dissolved oxygen and that the organisms be fed at a proper rate. In starting a plant, allow the aeration tanks to fill with settled sewage and start the aerators, setting them to operate continuously. Allow 30 to 50

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TABLE I
General Information Regarding Contributing Plants.

Plant	Connected Population	Type Sewers	Average Flow (MGD.)	Average Primary Sedimentation Period (Hr.)	Aeration Units: Type Aerators	Aeration Units: Number	Aeration Units: Average Aeration Period (Hr.)	Aeration Units: Cu. ft. Aeration Tank Capacity per Lb. Primary Eff. B.O.D.	Average 5-day B.O.D (ppm.): Raw Sewage	Average 5-day B.O.D (ppm.): Primary Effluent	Average 5-day B.O.D (ppm.): Final Effluent	Final Tank Collector Speed (Ft. per Min.)
Batavia, Illinois	4,700	Combined	0.895	0.45	American	7	4.62	57	287	70	9	1.0
Belvidere, Illinois	9,000	Separate	1.202	0.99	Chicago	9	7.00	49	223	126	5	0.75
Birmingham, Michigan	12,500	Combined	2.60	0.68	American	8	4.05	78	81	52	9.7	—
Bryan, Ohio	5,000	Combined	0.682	2.00	Chicago	6	9.26	109	102	67	10	2.0
Buchanan, Michigan	4,500	Separate	0.787	—	Chicago	3	3.10	46	96	56	21	2.0
Bucyrus, Ohio	9,600	—	1.066	1.5	American	6	6.00	45	263	126	4	—
Carlstrom Field	Restricted	Separate	0.067	1.5-3.0	Chicago(1)	2	10-20	99	181	138	3.6	—
Coldwater, Michigan	1,200	Separate	0.154	3.1	American	3	10.40	126	165	82	4	1.5
Crystal Lake, Ill.	5,000	Separate	0.30	—	Chicago	4	9.90	87	240	125	6	11.8
Dorr Field	Restricted	Separate	0.053	3.75	Chicago(1)	2	25.06	131	190	131	13	—
East Lansing, Mich.	13,500	Combined	1.838	1.20	American	9	4.80	107	79	40	4	10.0
Elmhurst, Illinois	16,000	Combined	1.50	1.60	Chicago	12	6.90	57	123	103	13	—
Ferguson, Mo.	12,000	Separate	0.80	2.0	Chicago	5	5.70	95	110	50	6	1.5
Geneva, Illinois	5,500	Separate	0.90	1.4	Yeomans	9	6.00	29	325	170	11	1.0
Great Lakes, Ill.	Restricted	Separate	Restricted	2.0	Chicago	12	10.00	—	375	225	19	2.0
Greece, New York	10,060	Separate	0.599	1.95	American	8	8.80	39	231	170	17	4.2
Illinois Ordnance	Restricted	Separate	0.100	5.32	Yeomans	3	22.00	163	150	130	1.5-3.0	1.0
Kewanee, Illinois	8,000	Separate	0.860	2.2	Yeomans	12	7.40	55	289	119	11	1.5
Knightstown, Ind.	500	Separate	0.060	—	Chicago(1)	2	—	—	—	—	—	—
Ladd, Illinois	1,200	Combined	0.070	1.75	Chicago(1)	2	17.00	37	—	—	—	—
Lambert Field	Restricted	Separate	0.250	1.2	Chicago	3	7.50	35	200	175	20	—
Laurens, S. Car.	5,700	Separate	0.480	0.50	Chicago	4	9.20	—	900	—	40	2.0
Milton Junction, Wis.	2,000	Separate	0.080	12.0	Yeomans	2	25.00	87	800	300	20	1.0
Radnor—Haverford, Pa.	10,400	—	0.80	1.0	Yeomans	8	10.00	91	172	104	7	—
Riddle Field	Restricted	Separate	0.015	6.4	Chicago(1)	1	42.00	330	165	92	7	—
Rochelle, Illinois	4,400	Separate	0.416	2.5	American	6	9.90	72	249	148	12	4.0
Stevens Point, Wis.	14,000	Separate	1.41(2)	2.0	American	6	7.60	25	270	180	10	4.0
Waterloo, Illinois	1,300	Separate	0.098	—	Chicago	2	15.00	150	232	89	26	0.5
Willow Run	Restricted	Separate	1.49	3.0	Chicago	16	12.00	76	155	129	18	1.0

(1) Combination Aerator—Clarifier. (2) 60 per cent given complete treatment.

per cent of the design flow to pass into the aeration tanks, by-passing the remainder of the settled sewage.

The Chicago Pump Co. (Operation Bull. No. 1165) suggests by-passing all settled sewage for 24 hours after starting the aerators and before allowing additional sewage to pass through the aeration tanks. After the final settling tanks are full, start the collecting mechanism and return sludge pumps (or open valve on automatic sludge return line*). The return of these previously aerated sewage solids will cause a gradual increase in the mixed liquor solids concentration. Walker, of the American Well Works, in notes for a lecture on activated sludge plant operation presented before the 1944 Illinois Sewage Works Operators' Short Course, stated:

"The quantity of sewage added to the aerated mixture is gradually increased from day to day. The return to the incoming sewage of the settled solids (taken from the final settling tank) from the previously aerated sewage will gradually increase the solids concentration of the aerated mixture. The addition of more sewage has to be done very carefully so as not to supply more organic food to the organisms than they can consume. Overfeeding of the organisms will have a very detrimental effect upon their existence because there will then be more organic matter being absorbed by the young activated sludge than it can digest. In a like manner, underfeeding has a very detrimental effect and it can be easily imagined that starved organisms do not thrive.

"Operate the plant at ⅓ to ½ rated (design) load and do not try to force the early activated sludge development. As the activated sludge starts to develop (recognized first by much white foaming and characteristic strong, spicy odor), increase the sewage load slowly.

"Stop applying the sewage load at once if the activated sludge seems to be reverting back to the air flocculated solids phase." (Note: Walker divides activated sludge development into two phases: first, the air flocculated solids phase, and, second, the true activated sludge phase.)

The mixed liquor solids concentration will gradually build up to a point where sufficient solids are present to permit turning the entire sewage flow into the aeration tanks. Operation Bull. No. 1165, of the Chicago Pump Co., suggests that this can be done when the suspended solids in the mixed liquor reach 400 ppm., and that careful wasting of activated sludge can be started when the suspended solids reach 600 to 800 ppm.

When starting a new activated sludge plant to serve a new sewer system it is nearly always found that the sewage flow is well below the design flow, which makes it advisable to begin operations, as described above, utilizing only a portion of the total aeration tank capacity of the plant. Similarly, if the plant is designed with more than one primary tank and final settling tank, it would appear desirable to start operations with only a portion of the settling capacity to avoid difficulties from overlong detention periods. Obviously, in the smaller plants this flexibility of operation of plant units is not common.

After the activated sludge has been developed, the operator finds that there are several variables over which he can and must exercise control in the operation of his plant. Those variables are:

1. Mixed liquor solids concentration.
2. Rate of returning sludge.
3. Application of air (amount of aeration).
4. Aeration period.
5. Condition of the activated sludge.

Those operation variables must be controlled by the operator to keep the plant in balance so that it can accommodate the normal loading received, and the same variables must also be regulated to accommodate fluctuations in loading, whether seasonal or otherwise. The comparison of control practices at the various plants contributing to this review clearly indicates the effect of local conditions upon control procedures.

American Well Works Mechanical Aeration Installation at McHenry, Ill.

*In the case of plants using American aerators.

Mixed Liquor Solids Concentration

The operation variable which usually receives first attention, and which is often considered the most important in activated sludge plant operation, is the mixed liquor solids concentration. The concentration of solids carried in the aeration tanks is adjusted by apportioning the activated sludge removed from the final settling tank between return and waste, this apportionment being accomplished in one of several ways, depending on the plant design.

In plants equipped for automatic sludge return (utilizing American aerators), wasting of activated sludge is usually controlled by a telescoping valve installed on the end of a sludge line branching off the return line and located in a waste sludge well. In plants employing pumps for returning sludge, the sludge is commonly pumped to a division box which can be manually adjusted to apportion the activated sludge between return and waste. In the case of the Chicago combination aerator-clarifier plant, a special waste activated sludge hopper is provided through which there is a circulation of mixed liquor at a controllable rate. Settling of waste activated sludge takes place in this hopper.

Data including the average and range of mixed liquor solids carried in the aeration tanks of 29 plants, together with the average sludge index and 30 minute mixed liquor settleable solids, are tabulated in Table II. These data indicate that fourteen of the plants carry average solids of 600 to 1,000 ppm., five plants carry average solids of 300 to 500 ppm., and one plant carries

TABLE II.

Mixed Liquor and Return Sludge Data

Plant	Mixed Liquor Suspended Solids (ppm.) Average	Range	Return Sludge: Average Return Rate (%)	Return Rate Range	Average Suspended Solids (ppm.)	Average Sludge Index	Average Mixed Liquor Settleable Solids (% in 30 min.)
Batavia, Illinois	824	806- 851	30	25-45	1,519	56	4.6
Belvidere, Illinois	557	416- 903	17	16-19	—	643	36
Birmingham, Michigan	2,000	1,500-2,600	28	22-34	10,700	70	11
Bryan, Ohio	711	557- 780	30	25-45	2,037	603	57
Buchanan, Michigan	676	530- 882	25	—	—	266	18
Bucyrus, Ohio	1,000	—	25	25-50	4,800	150	20
Carlstrom Field	840	260-1,400	—	—	—	631	53
Coldwater, Michigan	1,876	1,550-2,080	50	42-78	4,583	122	23
Crystal Lake, Ill.	550	—	25	—	—	85	4-10
Dorr Field	744	467- 910	—	—	—	483	36
East Lansing, Mich.	1,100	500-1,790	33	23-44	2,700	53	12
Elmhurst, Illinois	433	315- 655	27.5	16-41	—	530	22
Ferguson, Mo.	300	200- 600	25	20-30	—	360	13
Geneva, Illinois	621	443- 778	14	13-17	2,518	110	5
Great Lakes, Ill.	750	700-1,000	50	40-55	2,500	280	10
Greece, New York	1,036	669-1,470	17	7-39	4,170	173	19
Illinois Ordnance	900	500-1,400	46	—	2,250	48	7
Kewanee, Illinois	1,062	200-2,800	30	—	3,453	309	30
Knightstown, Ind.	800	—	—	—	—	800	50
Ladd, Illinois	600	300-1,000	—	—	—	167	10
Lambert Field	500	—	25	—	900	700	35
Laurens, S. Car.	600	500- 700	20	—	700	350	36
Milton Junction, Wis.	200	—	50	—	—	1,000	20
Radnor—Haverford, Pa.	900	800-1,000	40	35-45	2,000	155	18
Riddle Field	786	—	—	—	—	114	9
Rochelle, Illinois	445	310- 534	61	—	1,248	405	18
Stevens Point, Wis.	600	500- 900	50	40-60	1,800	135	10
Waterloo, Illinois	641	—	33	—	758	410	27
Willow Run	1,100	650-1,550	28	16-56	3,400	237	40

an average of only 200 ppm. Six of the plants carry average solids of over 1,000 ppm., two of which (Birmingham, Mich., and the Michigan State Home at Coldwater) carry averages of 2,000 and 1,876 ppm., respectively.

Grinnell (Birmingham, Mich.) states that his plant is normally operating at nearly 100 per cent overload, which makes it necessary to carry as high a mixed liquor solids concentration and index as possible in order to obtain good treatment at the short aeration period. At concentrations above 2,600 ppm. difficulty is experienced with floc carrying over the weirs of the final settling tanks, and this problem is accentuated when the volatile solids in the mixed liquor exceed 75 per cent.

Grinnell further states that he attempts to maintain a sludge as high in per cent volatile solids and as slow in settling as the plant flow loading will allow without carrying floc over the weirs. The sludge high in volatile content is, of course, more active. This is important in an overloaded plant in which it is necessary to obtain the most from the sludge concentration which can be carried. Grinnell states that two intercepting sewers lead to his plant, one of which carries very dilute sewage following rains. It is usually necessary to by-pass this sewage, which is high in ash content (fixed solids) due to the silt washed off the gravel streets in the contributing area. If the volatile content of the mixed liquor is high when a rain occurs, the high ash content sewage is carried into the plant for a time to reduce these high volatile solids, thus to make the sludge more dense so that it will settle in the final tanks at the increased rate of flow. If loading of the sludge with the silt-bearing sewage is carried to a point where the mixed liquor solids are lowered to 50 per cent volatile, or less, Grinnell states that an insufficiently active sludge results, as might be expected.

Tompkins (Michigan State Home, Coldwater) indicates that best results are obtained at his plant with an average mixed liquor solids concentration of 1800-1900 ppm. Decker (Bryan, Ohio) indicates that best results are obtained there when the mixed liquor solids are carried at 800 ppm. He indicates that about 100 ppm. higher mixed liquor solids are usually carried on Monday, the local washday, to compensate for the additional load.

Lamb (Belvidere, Ill.) carries an average of 557 ppm. of mixed liquor solids. He prefers to operate with mixed liquor solids as low as possible since it has been his experience that, while the plant might be somewhat more sensitive to upset at the lower solids concentrations, it will recover from an upset much faster than at higher solids values. Patriarche (East Lansing, Mich.) indicates that best results are obtained there at concentrations of 1,100 ppm., but states that the concentrations vary over a rather wide range in spite of efforts to control them. That this difficulty is similarly experienced in many plants is indicated by the rather wide range of mixed liquor solids reported from nearly every plant.

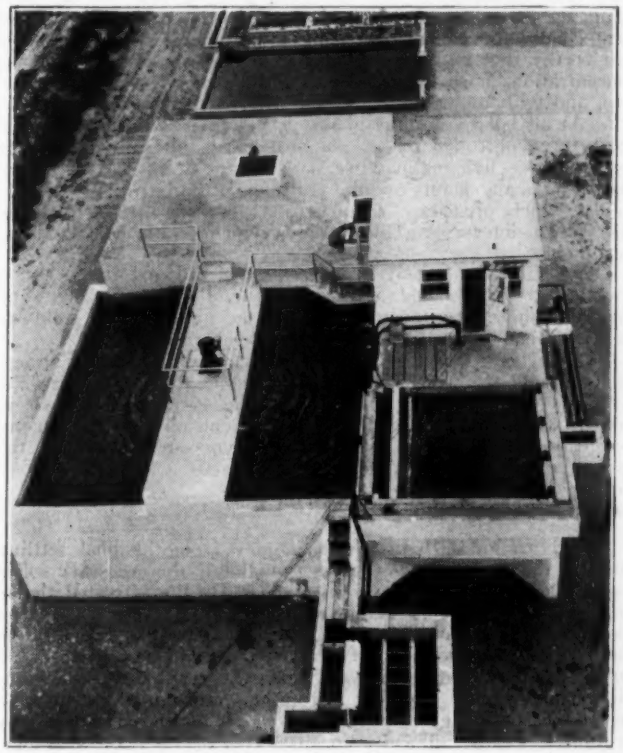
Denise (Greece, N. Y.) states that 800 ppm. of solids are carried during the summer months and about 1,100 ppm. during the winter months. It was not indicated whether a higher volatile solids content during the summer months enables lowering the mixed liquor solids, or whether there might be a drop in the load during the summer, which would appear rather unlikely. Carothers (Riddle Aeronautical Institute) indicates that his rule for mixed liquor solids is "the higher the better, commensurate with the oxygen supply."

Freeman (Geneva, Ill.) maintains approximately 620 ppm. of mixed liquor solids, but due to other duties which make it impossible to maintain as complete laboratory data as desired, mixed liquor solids are controlled on the basis of the settleable solids test, an effort being made to maintain between 5 and 8 per cent after 30 minutes. Lt. Comdr. Klay (Lambert Field, St. Louis) indicates that the settleable solids test on the mixed liquor is used to control the concentration, as does Bradley (Buchanan, Mich.) and Longley at Radnor-Haverford, Pa. Fischer (Kewanee, Ill.) attempts to maintain 800 to 1,000 ppm. of mixed liquor solids, and utilizes both suspended and settleable solids as a control basis for determining return sludge and wastage.

In general, the amount of mixed liquor solids which can be carried in a plant is limited only by the air supply and by certain hydraulic capacity factors. It is noteworthy here that mixed liquor solids concentrations as high as 2,600 ppm. are carried in one plant utilizing mechanical aerators, apparently without difficulty in supplying adequate aeration. The 2,600 ppm. of solids are carried at Birmingham, Mich., with operation of the aerators only 50 per cent of the time, and a dissolved oxygen content of 4.0 ppm. is maintained in the final aerator. It should be noted that the sewage at Birmingham is quite weak, however, an average aeration period of only 4.05 hr. being available. It appears that the solids concentration which can be carried in some mechanical activated sludge plants overlaps well into the range of solids usually associated with diffused air operation.

It is logical, from the standpoint of economic considerations, that no more mixed liquor solids be carried than necessary to meet the conditions under which a plant must operate and to permit obtaining the required effluent quality. Where the strength of sewage is widely variable, care must be exercised to maintain sufficient solids to handle the peak load. Most operators, particularly those operating plants treating widely variable sewages, must determine by intelligent trial and error methods the mixed liquor solids concentration which gives the best and most economical results, first emphasis being placed upon obtaining an effluent fitted to the outlet stream requirements.

The Chicago Pump Co. (Operation Bull. No. 1165) states that the operation of many plants utilizing Chicago mechanical aerators has indicated that for best results the mixed liquor solids should be from 600 to 1,000 ppm. Likewise, experience with their combination aerator-clarifier has indicated that best results are obtained in the 500 to 800 ppm. solids range. Yeomans Brothers suggests a range of mixed liquor solids from 300 to 1,000 ppm., with an average taken at about 500 ppm. They further point out the need for the experimentation to determine the optimum concentration for any given plant.



Chicago Pump Co. "Package" Plant at Consolidated Vultee Aircraft Corp., Miami, Fla.

At most of the mechanical activated sludge plants covered in this review, the suspended solids test is used as the basis for controlling the mixed liquor solids; however, at five of the plants it was indicated that the settleable solids determination is used for that purpose. Most of the plants reporting indicated that settleable solids in the mixed liquor are utilized largely as an indication of the general condition of the sludge and for computing the sludge index, and several operators referred to the difficulty in controlling a plant on the basis of settleable solids alone because of the variable settling characteristics of the sludge.

Cörtner (Indiana Children's Home, Knightstown) utilizes a centrifuge in controlling mixed liquor solids, in lieu of suspended or settleable solids, as does Lovejoy at Laurens, S. C. In that regard, it should be stated that there are many plants utilizing centrifuge results on mixed liquor as a control test.

The bulletin on "The Operation of a Chicago Combination Aerator-Clarifier Plant" states:

"It has been found that a centrifuge, either hand operated or electric, is a big help in controlling the concentration of solids in the mixed liquor. If the character of the sludge changes, the settling tests may vary greatly without any great change in the weight of the solids present, or vice versa. The centrifuge readings vary only slightly, regardless of the character of the sludge, being nearly directly proportional to the weight of solids present.

The centrifuge cannot replace the balance for accuracy, but is close enough for control of the mixed liquor solids and is far more accurate than the settling test alone.

"A centrifuge comes with two 15 cc. graduated tubes. Fill these to the mark with a well mixed sample from the aerator and insert in the holders. Spin for 3 minutes at 1,800 rpm. (2 revolutions per second with the commonly used hand centrifuge). Let the centrifuge die down without braking and read the sludge volume in the bottom. A reading of 0.25 to 0.40 ml. gives the proper amount of solids. This is approximately the same as 500 to 800 ppm. suspended solids."

A study of the average mixed liquor settleable solids data for the various plants, as tabulated in Table II, indicates a wide variation in per cent settleable solids for sludges of approximately the same suspended solids concentration, which is further verification of the need for intelligent and careful use of settleable solids if it is to be depended on as the sole basis for controlling mixed liquor solids concentration.

As a general average, in plants treating normal domestic sewages not containing troublesome industrial wastes, it may be stated that with activated sludges of good settling characteristics, 30-minute settleable solids in the 10 to 20 per cent range are most common.

Summarizing briefly, the following comments regarding mixed liquor solids control are offered:

1. Concentrations of 600 to 1,100 ppm. appear to be most common, although some plants operate below that range, and local conditions require that some plants operate above it. It is noteworthy that two plants included in this review are carrying concentrations normally associated only with diffused air operation, and without difficulty in supplying adequate aeration.
2. At all but five of the plants here represented, mixed liquor solids are controlled by use of suspended solids or centrifuge results, those five making use of settleable solids. It is recognized that many plants operate entirely on the basis of settleable solids, which procedure requires alertness on the part of the operator in interpreting the changes which occur in sludge settleability.
3. As stated by Wisely in his review of diffused air operation (see *Water Works and Sewerage*, June, 1944), it is suggested that there be no hesitancy in varying the mixed liquor solids to meet seasonal variations in load and temperature.
4. There does not appear to be evidence of any trend among the mechanical activated sludge plant operators to utilize the volatile content of the mixed liquor solids as a control basis in lieu of the total suspended solids, only one operator having an overloaded plant serving a combined sewer system indicating the use of volatile solids as a control.

Rate of Returning Sludge

The return of settled activated sludge from the final settling tanks to the aeration tanks serves to maintain the necessary solids concentration in the mixed liquor, and keeps the activated sludge in a usable condition. Sludge which remains in the final tanks too long will become septic and, upon its return to the aeration tanks, will exert a high oxygen demand, will not perform its purification functions effectively, and may readily cause a complete plant upset. Too low a rate of return may result in a septic return sludge; conversely, too high a rate of return may presumably cause difficulty in disposing of the excess sludge, due to the larger volume which would have to be wasted of the resulting dilute sludge in order to maintain the mixed liquor solids at the desired concentration.

Walker (American Well Works), in the lecture notes previously quoted, listed the following causes of a septic return sludge:

"1. The return pumping rate is not great enough and a blanket forms on the floor of the final tank, causing the activated sludge to be out of aeration too long.
"2. Faulty, slow or inefficient sludge conveying mechanisms in the final tanks.
"3. Bad draw-off hydraulics causing 'holes' to be pulled in the hoppers and leaving the sludge behind.
"4. Final tank units too large, making expeditious movement of settled sludge impossible.
"5. Not enough activated sludge available to treat the organic matter fed to it.
"6. Too much dense primary solid matter enmeshed in the activated sludge.
"Where return activated sludge is septic and reaeration is impossible, either increasing the aeration at the head end, or returning sludge at a number of points along the line of flow may prove helpful."

The rates of return sludge practiced in the plants contributing to this summary, together with the return sludge suspended solids data, are tabulated in Table II. Of the 24 plants indicating their return sludge rate, 12 employ rates between 20 and 30 per cent, eight employ rates between 30 and 50 per cent, one employs a rate of 61 per cent, and only three employ rates under 20 per cent. The data on the range of the return sludge rate indicate a considerable variation in the return sludge rate at a number of plants. Sludge return rates for the combination aerator-clarifier plants are not given, as the automatic return of sludge is a feature of that design.

The operation bulletin of the Chicago Pump Co. suggests that the rate of returning sludge should be at 20 to 25 per cent of the sewage flow, and warning is given against allowing the sludge to become septic at any point. Yeomans Brothers suggests a return sludge rate of 15 to 20 per cent, indicating it may be less than that, but they do not recommend a rate in excess of 20 per cent. Yeomans further suggests that the best rate of sludge return be determined by test so that the optimum mixed liquor solids concentration is maintained to produce the highest degree of treatment.

A study of the return sludge suspended solids data does not reveal any definite relationship between the concentration of return sludge and the rate of sludge return. Variations in sampling methods may explain this seeming inconsistency. It is generally expected that lower solids concentrations will result from the higher return sludge rates.

Of the plants commenting on the maintenance of a sludge blanket in the final settling tanks, 14 plants do not maintain a blanket, but seven plants indicate that a sludge blanket is maintained. In the latter cases, the depth of sludge blanket maintained was not indicated. The general tendency is to minimize the accumulation of a sludge blanket as much as possible, and it may also be stated that limitations in the sludge return facilities at some plants make it necessary to maintain a blanket. Some plants

Sectional View of Chicago Pump Co. Combination Aerator-Clarifier.

do maintain some sludge blanket so that this sludge will be available for shock loads; however, that practice was not referred to specifically by any of the plants contributing to this summary.

Application of Air

In diffused air activated sludge plant operation, the air must serve both as a mixing agent and to maintain the aerobic conditions required for effective operation. In a mechanical activated sludge plant, the air serves to satisfy the oxygen requirements of the activated sludge-sewage mixture and to maintain aerobic conditions, the mixing being accomplished by the mechanical aerator as it circulates the contents of the aeration tank. It is by means of this mechanical circulation that the conditions requisite for the entrainment of air in the mixed liquor are obtained. In a mechanical activated sludge plant the total quantity of air available is governed by the number of aerators in use and by the basic oxygenation capacity of the aerators, which is somewhat variable by means of adjustment of the equipment.

Certain of the Yeomans Brothers-Simplex aerators are equipped so that the amount of air applied can be varied by a simple adjustment of the speed of rotation of the aerator cone. Speed regulation from 30 per cent below to 30 per cent above normal speed is commonly provided.

The aerators of the Chicago Pump Co. are rated at about 6 ppm. of oxygen supplied to the entire tank contents per tank turnover, the number of tank turnovers per hour determining the basic oxygenation capacity rating. In an existing installation, the oxygenation capacity of Chicago aerators can be increased about 25 per cent by increasing the aeration propeller size, and about 150 per cent by increasing both propeller and motor sizes, according to their Bulletin 128-L.

The American Well Works aerators are of the injector plate and mixing well type, or of the type equipped solely with air intake tubes. In the well type, the water level in the well can be regulated by adjusting the openings in the injector plate, which also regulates the air input. In the air tube type, the quantity

of air applied can be readily adjusted by opening or closing the orifice unit on the air intake tubes.

For flexibility and economy of operation, the majority of mechanical activated sludge plants are equipped with time-clock control for the aerators which, by means of a simple adjustment, allows any desired operation-rest cycle during each cycle of the clock. The clock cycle is usually 15 or 20 minutes. The sewage strength at the majority of plants varies considerably, and for that reason it would not be economical to operate the aerators continuously at the same rate required for strong sewage at those times when a dilute sewage is received for treatment. In adjusting the time-clock control for the aerators the operator is nearly always guided by the dissolved oxygen content of the mixed liquor, most operators attempting to maintain a definite oxygen threshold before resorting to time-clock control.

TABLE III

Aerator Operation and Dissolved Oxygen Control

Plant	Average Operation of Aerators, Per Cent of Time	Mixed Liquor D.O. (ppm.) Inlet	Mid-point	Outlet	Final Effluent D.O. (ppm.)
Batavia, Illinois	76	1.0	2.5	5.0	3.2
Belvidere, Illinois	(1)	—	—	3.4	5.1
Birmingham, Michigan	50	—	—	4.0	2.0
Bryan, Ohio	50-100	0.1	2.0	3+	1.3
Buchanan, Michigan	100	—	—	5.5	—
Bucyrus, Ohio	85	—	—	—	5.6
Carlstrom Field	90	2.1	2.1	2.1	3.7
Coldwater, Michigan	90	—	—	6.0	5.0
Crystal Lake, Ill.	85	—	—	—	3.0
Dorr Field	90	2.7	—	—	2.9
East Lansing, Mich.	50-100	2.2	3.5	5.2	4.6
Elmhurst, Illinois	100	—	—	3.0	6.0
Ferguson, Mo.	65	—	—	4.5	5.0
Geneva, Illinois	100	0.2	2.2	3.0	4.6
Great Lakes, Ill.	80	2.0	—	1.5	0.2
Greece, New York	100	—	—	4.4	2.6
Illinois Ordnance	40	2.0	3-4	4-5	6.0
Kewanee, Illinois	77	—	—	—	2.7
Knightstown, Ind.	100	—	—	—	6.0
Ladd, Illinois	50	4.0	4-5	6.2	6.0
Lambert Field	62	—	—	3.0	2.0
Laurens, S. Car.	100	3.5	—	4.0	2.5
Milton Junction, Wis.	75	—	—	2.0	0.4-1.0
Radnor—Haverford, Pa.	100	1.7	2.8	5.0	4.6
Riddle Field	70	—	1.8	—	4.4
Rochelle, Illinois	100	1.8	4.0	6.6	4.1
Stevens Point, Wis.	66	—	—	0.3	0.8
Waterloo, Illinois	95	3-4	4.1	4.9	4.7
Willow Run	100	2.7	2.3	3.7	1.7

(1) Operated according to oxygen demand curve.

Table III indicates the average per cent of time that the aerators are in operation at the various plants, and also indicates average dissolved oxygen values in the mixed liquor at the inlet, mid-point and outlet of the aeration tank battery.

Decker (Bryan, Ohio) attempts to maintain 0.5 to 1.0 ppm. as a minimum dissolved oxygen concentration in regulating his time-clock control of aeration. Olson (Batavia, Ill.) has the last four of his six operating aerators on time-clock control, and he attempts to maintain a D.O. of 4.0 ppm. in the final aerator to meet shock loads of milk wastes. Grinnell (Birmingham, Mich.) operates his aerators to maintain a minimum D.O. of about 2.0 ppm. in the final effluent, which gives an average of 4.0 ppm. in the final aerator. The sewage at Birmingham is quite weak, and although 2,600 ppm. of mixed liquor suspended solids are carried at times, the operation of the aerators 50 per cent of the time has proved adequate.

Lamb, at Belvidere, Ill., made some rather extensive oxygen demand studies by means of the Odeeometer and determined a typical oxygen demand curve for the conditions encountered at Belvidere. He states:

"The curve shows that at Belvidere large amounts of air are needed to satisfy the demand during the first 15 minutes of aeration period, and that at least a 7-hour aeration period is needed. By operating aeration units in accordance with this curve, we have obtained excellent operation with economy. Before operating in accordance with this curve, tests showed that there was considerable variation in the oxygen demand of the return sludge. On many occasions this demand was considerably higher than could be furnished by the aeration units.

"Tests taken after operating in accordance with the oxygen demand curve show that operation by this method eliminates excessive oxygen demand of the return sludge, and keeps the demand down where the aerators can meet it.

"The economy of operation is attested by the fact that power consumption has been reduced from a previous figure of 0.371 kw. hr. per lb. B.O.D. removed in 1938 to 0.293 in 1939, 0.281 in 1940, and 0.257 in 1941.

"Aerators are cut in and out of service and time-clock operation used in order to meet the changing oxygen demand brought about by changes in either the volume or strength of the sewage." (Note: A complete description of the experimental work done by Lamb, and its interpretation in plant operation, is given in his thesis, "The Operation of an Activated Sludge Treatment Works with Special Reference to the Treatment of Cannery Wastes and the Oxygen Demand of Sewage and Activated Sludge Mixtures," University of Illinois Graduate School, 1940.)

Lamb further states that dissolved oxygen tests are made twice daily on the mixed liquor in the final aerators in each of the three batteries, and a low D.O. in the evening followed by a substantial recovery the next morning indicates economical operation in accordance with the oxygen demand curve.

Howe (Illinois Ordnance Plant) operates the aerators a sufficient time to produce an effluent in which the dissolved oxygen content is as great or greater than the B.O.D. of the same effluent. The Illinois Ordnance Plant is operating considerably below the design flow, and as a result the lift stations operate at irregular intervals causing the sewage flow to be received more or less as shock loads. Due to the long aeration period available, however, operation of the aerators during 40 per cent of a time-clock cycle has proved adequate to maintain a high degree of treatment.

Patriarche (East Lansing) finds that as long as a slight amount of dissolved oxygen can be maintained in the return sludge, his plant is operating satisfactorily. A dilute sewage during the spring months makes 50 per cent time-clock operation of the aerators adequate, but nearly 100 per cent operation is considered necessary during the summer. An average D.O. of 5.2 ppm. is maintained in the final aerator. Patriarche states that a tapered aeration schedule has been tried, but that better results are obtained by operating all aerators the same percentage of time.

Yeomans-Simplex Mechanical "Aerifier" at Gulf Shores, Fla.

Denise (Greece, N. Y.) indicates that about 2.2 hours' preaeration of the primary effluent is standard operation, the sewage leaving the preaerator having a D.O. of 1.5 to 3.0 ppm. One hundred per cent operation of the aerators maintains a minimum of 4.0 ppm. D.O. in the final aerator. Tanari (Ladd, Ill.) indicates that from 4.0 to 6.0 ppm. D.O. seems to be necessary to prevent bulking, which is probably caused by milk wastes.

Wolf (Waterloo, Ill.) attempts to maintain at least 3.0 ppm. of dissolved oxygen before resorting to time-clock control, as does Tompkins at the Michigan State Home. Tompkins has one time-clock for controlling the last two of the three aerators, the first aerator being run 100 per cent of the time. Lt. Comdr. Klay (Lambert Field) indicates that an average D.O. of 3.0 ppm. is maintained in the final aerator.

Fischer (Kewanee, Ill.) has operated on a tapered aeration schedule, operating four aerators 100 per cent, four at 75 per cent and four at 50 per cent of the time. Lovejoy (Laurens, S. C.) indicates that his plant was designed for tapered aeration, consequently all aerators are run continuously.

Miller, at Great Lakes, operates the mechanical aerators 80 per cent of each clock cycle. Due to the exceptionally strong sewage at Great Lakes it was found necessary to supplement the mechanical aeration with diffused air at approximately 1 cu. ft. per gallon, equivalent to about 490 cu. ft. per pound of B.O.D. removed. The supplemental diffused air system was designed for tapered aeration. Dulmage (Willow Run Bomber Plant) indicates that 100 per cent operation of the aerators has been necessary to maintain sufficient dissolved oxygen in the aeration tanks.

Several operators referred to the need for building up dissolved oxygen in the mixed liquor to meet shock loads.

Aeration Period

Stronger sewages require longer aeration periods in order to obtain a high degree of treatment, although some adjustment can be made by varying the mixed liquor solids within the limits of the air supply. Adjustments in the aeration period are made by placing aeration tanks in or out of service.

Table I lists the average aeration periods for the contributing plants. A wide variation in available plant capacity is indicated. In studying the aeration periods and sewage strengths indicated, it is not surprising that a considerable variation in operation control practices exists.

At six of the plants reporting, aeration periods between 3 and 6 hours are indicated; at six plants aeration periods in the 6 to 9 hour range are reported; at six plants aeration periods are in the 9 to 12 hour range. The remaining plants have aeration periods in excess of 12 hours. One plant, which is a combination aerator-clarifier plant operating far below capacity, actually has a 42-hour aeration period. Carothers, at that plant (Riddle Field, Clewiston, Fla.), indicates some difficulty with rising sludge in the final tank due to overaeration.

Few of the plants included in this review indicated that the aeration period is used as an operation control. Lamb (Belvidere) does place aeration tanks in and out of service as required by the sewage flow and strength, as does Freeman (Geneva). Denise (Greece) used four or five of the available eight aeration tanks during 1943 to maintain an average aeration period of 8.8 hours.

None of the plants indicated that reaeration of return sludge is practiced, although Decker (Bryan) suggested that some aeration of return sludge is effected in his plant by the unusual design, which provides a seven-foot fall from the return sludge draw-off pipe, and two additional cataracts of five feet from the sludge division box.

Normally, plants having adequate aeration periods have less difficulty maintaining a well conditioned activated sludge and, therefore, are less affected by shock loads than plants which must operate with a low aeration period, low to the extent that it must be compensated for by carrying higher mixed liquor solids.

Condition of the Sludge

The operator is constantly guided by the condition of the activated sludge in controlling the operation variables, and the maintenance of a well conditioned sludge reflects the success of the operation procedures, although at times the activated sludge assumes characteristics which can be controlled with extreme difficulty if at all. In determining the condition of the activated sludge, the operator is most commonly guided by some or all of the following observations:

1. Physical appearance, both in the aeration tank and in the laboratory, and odor.
2. Settling characteristics, and sludge index.
3. Microscopic examination.
4. Sludge activity, often referred to as oxygen demand, as determined by the Odeeometer or by direct chemical methods.

Appearance and Odor.—A well conditioned activated sludge is usually golden to moderate brown in color, has a pronounced, spicy (sometimes described as earthy) odor, and, upon becoming septic, assumes a sour odor and a gray to black color. A sample of a well conditioned activated sludge, when allowed to settle in a graduate, will usually become gas lifted to the surface in a few hours.

A well conditioned activated sludge, when placed in a glass cylinder, will quickly form itself into clearly defined flocs and then settle readily. As the sludge mass begins to settle, an upward movement of some flocs within the settling sludge mass is usually apparent as other flocs subside.

An experienced operator can usually determine from the appearance of the mixed liquor in the aeration tanks, to some extent at least, whether a well conditioned sludge is being maintained. In that regard, the Operation Bulletin of the American Well Works suggests:

"Another way of judging the condition of the aeration tank is to notice if the tank has a lively, active look while the air diffusion unit is running. Foam should be plentiful and white, and an active bubble pattern should form. When the machine is stopped, the sludge should rapidly crease and form furls. These furls should keep constantly changing and moving. If the sludge is in poor condition, the tank will have a dead look while the machine is running. There will be little or no foam present and the color of the sludge will change from brown to a pasty gray. When the machine is stopped the sludge will lie with an even surface and there will be no immediate creasing and furling."

Settling Characteristics and Sludge Index.—The success of activated sludge plant operation depends largely on maintaining the settleability of the activated sludge since the ready separation of the liquid and the sludge in the final sedimentation units is the final prerequisite to the production of a good effluent. Disregarding activated sludges affected by industrial wastes, thirty-minute settleable solids in the 10 to 20 per cent range are most common. Values above and below that range are also quite common, as the data in Table II would indicate.

The sludge index (Mohlman), commonly defined as the volume in mililiters occupied by one gram of sludge after thirty minutes' settling, is an expression of the density of the activated sludge and is found to be a helpful guide in plant operation. A rising sludge index may indicate underaeration, an overload, or a bulking tendency. The wide variation in average sludge index among the plants contributing to this summary, as listed in Table II, is most interesting and indicates the importance of determining the optimum operating range for any given plant. An index attendant to normal operation at one plant may occur during impending or actual bulking at another plant.

Microscopic Examination.—The use of the microscope in observing activated sludge condition is reported by five plants. Longley (Radnor-Haverford) reports weekly observations to check for *Sphaerotilus natans.* Miller (Great Lakes) makes daily microscopic examinations of mixed liquor and return sludge to check for *Sphaerotilus* and to observe the activity and types of organisms. Dulmage (Willow Run Bomber Plant) uses the microscope to check the general appearance of the sludge as a parameter of sludge condition. Occasional observations are made at Kewanee, Ill., and at least weekly at Michigan State Home.

Sludge Activity.—The oxygen utilization rate of the sludge in ppm. per hour, commonly referred to as sludge activity or oxygen demand, as determined by the Odeeometer or by direct chemical methods, is not utilized in most mechanical activated sludge plants. Of the plants included in this review, only Lamb at Belvidere has made use of extensive oxygen demand studies in plant operation, as previously recounted in this review.

Operation Problems

Bulking of Activated Sludge.—Nearly every activated sludge plant has at some time experienced a bulking condition of the activated sludge which is characterized by the loss of sludge settleability to such an extent that natural tank currents carry the sludge over the weirs. Bulking tendencies naturally occur with varying severity, and bulking may follow any condition from a mild expansion of the activated sludge to one in which there is little or no settlement of the sludge. Whether or not bulking will occur with any given degree of loss of sludge settleability will depend upon final settling tank flow velocities. At some plants, overloaded as to flow rate, a loss of solids occurs which is the direct result of excessive overflow rates in final sedimentation units. This condition simulates bulking but is not related to activated sludge condition.

Of the plants represented here, eight reported little or no trouble, two gave no reply, and the remainder indicated bulking difficulties with summarized causes as follows:

1. Shock loads from industrial wastes reportedly account for bulking at eight plants. Milk wastes and wastes containing excessive grease content were the major reported causes of bulking attributed to industrial wastes. The plant at Laurens, S. C., reports bulking due to shock loads of starch and dye wastes from a textile industry.

2. Septic sewage was listed as a cause of bulking at five plants, three of which indicated this difficulty usually follows a rain which flushes accumulated septic sewage solids from combined sewers. Difficulty with the carryover of waste activated sludge back to the aeration tanks was listed as a cause of bulking at several plants. Bulking sometimes follows the discharge of heavy supernatant liquor to the raw sewage at a number of plants.

3. The loss of operation balance was referred to by Bradley (Buchanan) and Patriarche (East Lansing) as basic causes of bulking. Patriarche specifically referred to bulking as resulting from too high or too low mixed liquor solids. Inadequate aeration might also be a cause.

4. It is common for overloaded plants to experience chronic bulking which defies the usual remedies. In cases of consistent organic overloading, unless the cause lends itself to ready reduction through pre-treatment or other practices, plant expansion is usually indicated for chronic bulking elimination.

5. High pH in the mixed liquor was attributed by Carothers (Riddle Aeronautical Institute) as a cause of bulking at a plant serving a military camp having a lime-softened water supply.

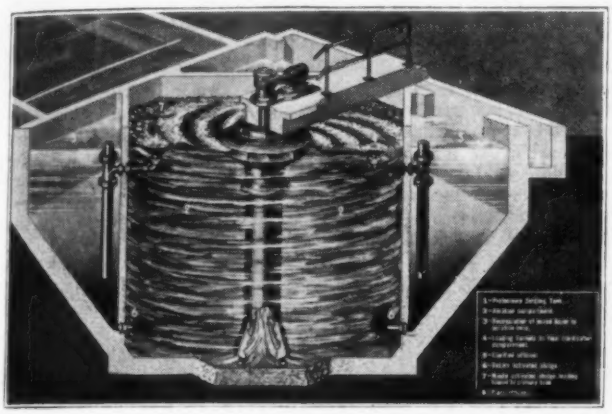
Continuous, careful attention to the operation variables will prevent many cases of bulking, as will the exercise of careful and intelligent control over industrial wastes discharging to the sewers. Requiring industry to provide pretreatment of troublesome wastes, removal of toxic wastes, and/or flow equalization

equipment to assure more uniform rates of discharge to the sewers often will minimize industrial waste influences.

If shock loads are a known cause of mulking, and if the loads are of such intensity that compensation or adjustment of operation variables may prevent or minimize some such cases of bulking, then it is obviously advantageous to learn to recognize promptly the receipt of a shock load so that preventive adjustments in operation may be made immediately. Air application and return sludge rate are commonly increased to meet shock loads. Either or both visual observations and analytical determinations may serve to indicate receipt of shock loads, depending on the nature of the wastes involved.

A common practice among operators upon the first evidence of bulking is to increase the application of air and the return sludge rate. If possible, reducing the load applied to the aeration tanks is a helpful adjunct since the intensity of loading is normally closely associated with bulking tendencies. Dick (Elmhurst, Ill.) indicates bulking control by increasing rate of return sludge and sludge wastage (probably applied after bulking is in progress).

Chlorination of the return sludge is utilized at Great Lakes, Batavia, Bucyrus, and Radnor-Haverford as a remedy for bulking. Miller (Great Lakes) begins chlorination of the return sludge at the first evidence of impending bulking, a dosage of about 4 ppm., based on raw sewage flow being utilized. Longley (Radnor-Haverford) indicates that bulking occurs frequently, but reports excellent control by chlorination of the return sludge at a dosage of 10 ppm., based on the return sludge flow.



Sectional View of Yeomans-Simplex "Aerifier."

Olson (Batavia) reports varied success in bulking control with the use of copper sulfate, and Todd (Milton Junction, Wis.) reports some success with the use of lime. Patriarche (East Lansing) controls bulking by the careful discharge of heavy supernatant liquor (20,000 to 40,000 ppm. suspended solids) direct to the aerators, at the same time increasing the application of air, if possible. This method is used at the first signs of bulking as a preventive measure rather than a cure, and Patriarche reports that, if done carefully, it has always been very effective. A well conditioned activated sludge is usually restored, at East Lansing, by this method in about two days. Patriarche cautions that the mixed liquor solids concentration must be carefully watched.

Denise (Greece, N. Y.) reports that no bulking has occurred there since the practice of aerating the primary effluent prior to adding the return activated sludge was established. An average aeration period of 2.2 hours is utilized for that purpose, and the primary effluent contains 1.5 to 3 ppm. of dissolved oxygen when the return activated sludge is added. This procedure freshens the sewage and reduces its oxygen demand, and is most helpful in cases where a septic sewage is received. Preaeration before primary sedimentation of a septic sewage would probably be of greater overall benefit; however, few plants are so equipped.

Carothers (Riddle Aeronautical Institute) indicates that bulking was attributed to too high a pH in the sewage at a military camp in Florida. He indicates that this pH is lowered in the primary tanks from 9.5 to 7.8-8.1 by merely stopping sludge pumping from those tanks, the drop in pH being attributed to the bubbling of the CO_2 gas, formed in the settled sludge, through the sewage flowing through the primary tanks. He indicates a content of 15 to 20 ppm. free carbon dioxide in the primary effluent. The sludge is skimmed off and pumped to the digester as soon as it is gas-lifted to the surface.

The problem at this plant is an unusual one, and the operation procedures indicated by Carothers are unusual and certainly unorthodox. An unusual combination of circumstances must exist to permit the successful use of the practices described by him, and high prevailing temperatures may be a factor. Primary tank efficiencies at Dorr and Carlstrom Fields are low, as would be expected as the result of the practices described by Carothers; however, it should be observed that available aeration periods are very long.

To restore the condition of a bulked activated sludge, common practice is to waste all or part of the bulky sludge, the amount wasted usually depending on whether or not sludge wasting and disposal facilities are limited. Denise (Greece) reports that prior to the utilization of preaeration of the primary effluent, when bulking occurred it was controlled by wasting down to 400 ppm. suspended solids in the mixed liquor and building up again to the normal concentration.

Rising Sludge in Final Clarifiers.—Rising sludge, a condition in which large masses or clouds of sludge rise to the surface of the final settling tanks, is attributed to a number of causes by the operators contributing to this summary.

Rising sludge attributed to overaeration occurs at Waterloo, Dorr Field, Riddle Field, Laurens and Rochelle. At the latter two plants the rising sludge condition follows a drop in the industrial wastes load, and Lovejoy, at Laurens, wastes sludge as a control measure. This condition is rather common at plants handling fluctuating industrial wastes loads, and it may occur at any plant when the load falls off considerably. Decreasing air application and reducing mixed liquor solids may prove helpful; however, when reducing mixed liquor solids it should be borne in mind that the heavier loadings can be anticipated to return.

It is difficult, and often impracticable, to adjust mixed liquor solids to load variations closely enough to prevent some degree of rising sludge from developing. The rising sludge condition which sometimes occurs when nitrification is high is commonly attributed to the reduction of nitrates in the sludge, the liberated nitrogen bubbles buoying the sludge masses to the surface. High nitrification commonly accompanies overaeration of the sludge, as does the presence of pin point floc in the plant effluent.

A condition, termed as rising sludge by the operators, occurs during the peak flows at Bryan, Batavia, Birmingham, Belvidere and Willow Run. This condition is probably closely associated with overflow rates and final settling tank velocities. Decker (Bryan) controls this condition by checking the sewage flow and backing up sewage in the outfall sewer during the peak flow. Lamb (Belvidere) indicates some success by increasing the return sludge rate. Dulmage, at Willow Run, has had some success in controlling this condition by discharging filtrate from the sludge filter into the inlet channel of the final settling tanks.

Septic conditions in the final settling tank sludge blanket will often result in the rising of masses of sludge to the surface. This was specifically referred to by Todd (Milton Junction), and is a basic reason why the majority of plants do not maintain a sludge blanket. This condition might occur if the final tank sludge collection mechanism was improperly installed or has been damaged.

Grease and Oil.—The receipt of undue quantities of grease or oil can seriously affect activated sludge plant operation. Six of the plants contributing to this review indicated some operation difficulty from oil or grease.

Grease may affect operation by acting as an organic overload, or by directly damaging the activated sludge into which it is readily absorbed. Impregnation with grease seems to reduce the oxygen absorbing powers of activated sludge, thus limiting the oxidizing capacity of the sludge which is reflected in the final effluent quality. This effect may be more pronounced when oil is received in quantity.

In lecture notes previously referred to, Walker (American Well Works) stated with reference to grease:

"Grease passing into the aeration tanks will be readily adsorbed by activated sludge. This adsorption is accumulative since the activated sludge cannot rapidly convert the grease adsorbed. Very soon (depending on the amount of grease and the amount of activated sludge) the activated sludge becomes composed of one-half or more of grease, and goes septic and useless, even though completely aerobic conditions surround the floc. This is a case of putrefaction going on internally in the sludge floc, even while a residual of dissolved oxygen exists in the surrounding liquor.

"When the activated sludge has adsorbed too much grease it loses its spicy odor and other activated sludge characteristics. It will turn to a light gray or black color and will refuse to settle well in the final settling tank. The effluent will develop a suspended turbidity which will be obvious in the clarity test. This increase in turbidity (diminishing final clarity) generally precedes the poor settling condition and is nearly always a good danger flag to the operator that all is not well."

Primary sludges or activated sludges high in grease content usually do not concentrate well, resulting in a digester operation problem at some plants. In addition to other effects, the pumping of a thin sludge to the digester results in a correspondingly larger quantity of supernatant liquor, which often creates a difficult disposal problem.

Waste Activated Sludge Disposal.—Of the plants contributing to this summary, eleven reported difficulty with waste activated sludge disposal, nine reported no difficulty, and the remainder indicated the method of disposal without further comment.

The most common method of handling waste activated sludge is to discharge it to the raw sewage so that the waste solids can be removed to the digester, along with the primary solids, after concentration in the primary settling tanks. That the method is not always satisfactory, however, is attested by the fact that of twenty plants utilizing it, eleven indicated that difficulties are encountered, and several others indicated that it must be practiced with care.

Failure of the waste activated sludge to settle out in the primary tanks during peak flows, thus imposing a recirculating load on the aeration tanks, was indicated at East Lansing, Lambert Field and Radnor-Haverford. Olson (Batavia) indicates that difficulty is most pronounced at times when a septic raw sewage is received. Browne (Bucyrus) indicates the waste sludge does not settle readily in the primary tanks when it contains appreciable grease and during the dry weather months (probably associated with the high volatile solids commonly prevalent during such periods).

Dulmage (Willow Run) wastes activated sludge continuously to the primary tanks, and adds milk of lime to the waste sludge at times to prevent its carryover into the aeration tanks. Enough lime is added to raise the pH of the waste sludge to a maximum of 9.0, and the method has met with some success. Wolf (Waterloo) and Krueger (Ferguson) refer to the necessity for frequent pumping of the raw-waste sludge mixture from the primary tanks. Failure to do so often results in septicity of the sludge mixture, accompanied by rising sludge masses in the primary tanks.

Several operators referred to the importance of wasting activated sludge at a low, uniform rate, particularly if primary sedimentation periods are low. Lamb (Belvidere) wastes sludge during the night when the sewage flow rate is low. Decker (Bryan) wastes sludge to the primary tanks continuously at a low rate and he indicates that, although a rather dilute mixed sludge results, less difficulty is encountered than when a concentration box was used for the waste sludge. Denise (Greece) indicates that the raw-waste sludge mixture is usually not well concentrated when pumped to storage or thickener tanks prior to vacuum filtration and incineration.

Howe (Illinois Ordnance) indicates that waste activated sludge is pumped to a concentration well and thence to the digester. This practice is unusually successful at that plant, as indicated by the 3 to 4 per cent sludges reported to obtain. Activated sludge wasting through primary settling tanks is often a problem when the sludge indicates a bulking tendency, or is actively bulking, as the waste sludge may not settle, thus imposing a recirculating load on the aeration tanks. This condition may greatly hamper efforts to restore activated sludge condition, since common practice is to increase greatly activated sludge wasting when bulking is out of control. Difficulties arise with nearly all methods of waste sludge disposal when bulking occurs.

Chironomus Larvae.—Although most of the plants contributing to this summary indicated that the *chironomus* fly larvae, more commonly called the bloodworm, have not been a problem, three of the plants reported that the larvae have caused interference with operation. At Michigan State Home, Tompkins reports the bloodworms constitute his most troublesome operation problem, and on occasion they have completely halted plant operation.

The larvae of the *chironomus* fly are bright red worms, commonly reaching lengths of one-half to one inch. The average life cycle of the fly is reportedly about five weeks, and under favorable conditions they multiply rapidly. The larvae surround themselves with sheltering cocoons of whatever material is available, and when activated sludge plants are infested the cocoon is formed of the activated sludge. The cocoons of sludge commonly adhere to tank walls for a while, then break loose and float on the final settling tank surface. The cocoons may break up and result in the formation of a thin layer of sludge on the tank surface. The heavy infestation of a plant may result in a serious loss of activated sludge, and in some plants the sludge has virtually disappeared overnight.

Tompkins (Mich. State Home) indicates screens have been placed over channels and quiescent portions of the final settling tanks to keep the flies out. He also indicates some benefit by maintaining a film of oil wherever possible. Denise (Greece) reported that difficulty with *chironomus* larvae was experienced during initial operation, and the only successful control was to clean out the entire plant and start over.

Pyrethrum, copper sulfate, and chlorine have been tried as control measures, usually with indifferent results. It is commonly conceded that dewatering and scrubbing infested tanks is the most effective control.

The *chironomus* larvae may be present in limited numbers without detrimentally affecting operation; however, they may readily develop into a major problem and their presence is always cause for concern.

Supernatant Liquor Disposal.—Probably the most common method of disposing of supernatant liquor is to return it to the raw sewage. This method of disposal is utilized at thirteen plants contributing to this review, with several of those plants indicating that alternate methods of disposal are available.

Olson (Batavia) reports this method as "a nasty practice and one difficult to control." Howe (Ill. Ordnance Plant) reports no difficulty when supernatant liquor is drawn slowly and carefully to the raw sewage. The supernatant liquor at Illinois Ordnance averages 800 to 1000 ppm., B.O.D., and only 110 ppm. suspended solids—a good supernatant at any plant. Tompkins (Mich. State Home) discharges a supernatant having an average of 619 ppm. suspended solids to the raw sewage without difficulty.

A supernatant containing 661 ppm. suspended solids is similarly disposed of without difficulty by Dulmage at Willow Run. Freeman (Geneva) reports that a supernatant having an average B.O.D. of 610 ppm. and suspended solids of 1730 ppm. is disposed of satisfactorily to the raw sewage if drawn slowly. Bulking results at Geneva if the supernatant liquor is drawn to the raw sewage at too high a rate.

Four plants reported disposal of supernatant liquor direct to the aeration tanks. Patriarche (East Lansing) refers to the necessity for carefully watching the mixed liquor solids concentration when utilizing that method of supernatant disposal. Considerable use is made of supernatant liquor at East Lansing to regulate and control the mixed liquor. This is interesting, particularly when considering that the supernatant liquor suspended solids average 25,000 ppm. Alternate disposal to the sludge drying beds is available.

Fischer (Kewanee) draws supernatant liquor into an idle aeration tank for storage and then discharges it to an operating aeration unit at a controlled rate. He states that this method has not proved too satisfactory. Dulmage (Willow Run) draws supernatant either to the aeration tanks or to the raw sewage. He cautions that supernatant liquor disposal to the aeration tanks must be done with care.

Browne (Bucyrus) indicates that when disposing of supernatant liquor to the aeration tanks, it is discharged at a low, continuous rate near the middle of an aeration tank battery. When supernatant liquor quality indicates it cannot be discharged direct to the aeration tanks at Bucyrus, it is discharged to a supernatant treatment tank equipped with an American Well aerator, this tank being operated on a fill-and-draw basis. The supernatant liquor is aerated, and coagulants and chlorine may be added if necessary. After this treatment, the settled sludge is returned to the digester and the clarified supernatant is withdrawn to the raw sewage. Browne reports very successful use of that treatment method.

A Pacific Flush Tank "atomizing" aeration-settling unit has been installed at Great Lakes for supernatant liquor treatment. Operating results were not yet available, as the installation was just completed and was undergoing minor adjustments when the questionnaires for this summary were distributed. Similar units at other plants have performed well, according to published data. Decker (Bryan) found it possible, through valve manipulations, to draw supernatant liquor into an idle flash mixing tank, where it is aerated and then discharged to the raw sewage during the night and low flow period. The supernatant liquor is drawn to the flash mixing tank at a slow rate.

At Belvidere, Indiana Soldiers and Sailors Children's Home, Dorr Field, Carlstrom Field, and Ferguson, supernatant liquor is disposed of by discharge of sludge drying beds. Lamb (Belvidere) reports this method of disposal proves satisfactory, but that the supernatant liquor dries slowly. Bradley (Buchanan) disposes of supernatant liquor to a lagoon, as does Russell at Rochelle. Lovejoy (Laurens) discharges supernatant liquor to the river.

Supernatant liquor disposal constitutes one of the most common operation problems, particularly in plants practicing its disposal to the raw sewage. At plants utilizing this method of disposal, it is a helpful precaution to provide an alternate method, such as a lagoon or drying bed, to be utilized when a poor quality supernatant is present.

A poor quality supernatant liquor, if discharged to the raw sewage or to the aeration tanks, may result in a poorly settling activated sludge, which results in larger volumes of sludge for transfer to the digester, and thus in larger volumes of supernatant liquor for disposal. Whether a plant can handle supernatant liquor in the aeration tanks without pretreatment depends on the degree of loading of those units and on the quality of the supernatant liquor.

OXIDANTS AND REDUCTANTS IN SEWAGE PLANT EFFLUENTS AND STREAMS

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THE relationship between stream conditions and the quality of effluents from sewage treatment plants employing biological secondary processes of theatment has been the subject of considerable discussion of late among sanitary engineers. Differences of opinion have arisen over the relative merits of the relative stability and B.O.D. tests as indices of effluent quality. Both tests have been in use for many years; the test selected frequently depending upon the laboratory facilities available and the analytical skill of the operating personnel. The two tests are quite different in nature and bear no direct relationship.

A revaluation of the significance and applicability of each test and a study of fact as involved in the two tests, together with evaluation of the influence of nitrates on the receiving stream is timely. It should serve to clarify the situation and suggest practical criteria in determining effluent quality and its relation to the stream.

Proper Basis for Judging Effluent Quality

The proper basis for judging the quality of effluents from sewage treatment plants should be the degree to which the particular effluent meets the requirements of the criterion established for the receiving stream conditions. As far as oxygen in the stream is concerned, two criteria present themselves. One is governed by the necessity for preservation of fish life. This usually calls for the maintenance of at least 3 ppm. of dissolved oxygen in the stream at all times. The other criterion is the control of odor nuisances and prevention of septic conditions in the stream. The design of any sewage treatment plant should be predicated upon the ability of the receiving stream to absorb the plant effluent in such a manner that it meets one of the above criteria (or perhaps bacteriological criteria) whichever has been established by stream control authorities.

Characteristics of Effluents

Primary treatment plants are characterized by effluents which contain appreciable amounts of organic matter in the form of dissolved, colloidal and suspended solids. Tests indicate that the effluents are high in B.O.D., ammonia and organic nitrogen and usually devoid of dissolved oxygen, nitrites or nitrates. Considerable dilution is necessary to maintain acceptable conditions in the receiving stream.

Secondary treatment plants operating at normal efficiency are characterized by effluents which are low in organic matter, as measured by the B.O.D. test. Low rate trickling filter plants yield effluents which frequently are high in nitrates and relative stability. On the other hand, operating data on high rate filter plants indicate that the effluents contain little or no nitrites or nitrates and have a low relative stability even though the B.O.D. values may be the same as those of the low rate filters. In other words, the nitrification of organic matter proceeds further in low rate than in high rate filters. Activated sludge plants can impart either a low or a high degree of nitrification to the organic matter depending on the amount of air used, length of aeration and other factors which control the operation of this type of plant.

The Relative Stability Test

Consideration should first be given to the reactions taking place in the relative stability test bottle. Assume that a 150 ml. bottle has been filled with the effluent from a low rate trickling filter, with the requisite amount of methylene blue indicator added. In addition to other substances, this effluent will contain organic matter chemically classified as reductants and dissolved oxygen, nitrites, nitrates, and sulphates, termed oxidants. The test procedure calls for incubation of the bottle at 20 deg. C. until the methylene blue turns colorless. The period of incubation in days is noted and converted to a percentage known as the "relative stability." This percentage is based on the arbitrary assumption that a sample in which methylene blue retains its color for 20 days is 99 per cent stable. Intermediate values follow a logarithmic relationship between oxygen demand and time.

During the course of the incubation the organic matter serves as food for the organisms present in the sewage sample. These organisms utilize oxygen in their life processes. Oxygen is most readily obtained when in the free state as dissolved oxygen. When this is no longer available, oxygen is obtained from other oxidants such as nitrites, nitrates and sulphates. The biochemical reactions taking place result in the oxidation of organic matter and the reduction of oxygen and other oxidants. When these oxidants are virtually used up the methylene blue loses its color and the test is completed.

The loss of color of methylene blue is brought about by a chemical oxidation-reduction reaction. Methylene blue is an organic dye compound which can be oxidized or reduced by means of bacteria the same as other organic matter. It has the property that when in the reduced state it is colorless, known as leuco-methylene blue. If oxygen were added to a solution containing the reduced compound it would be oxidized to the blue color. This change of color occurs at an oxidation-reduction potential of approximately zero. Thus, methylene blue serves as an indicator of zero oxidation-reduction potential. This is the use to which it is placed in the relative stability test.

Oxidation-Reduction Potentials

It is not the purpose of this short paper to describe all of the physical and chemical factors involved in oxidation and reduction reactions. However, a brief consideration of oxidation-reduction potentials might serve to give a clearer picture of what lies behind the relative stability test and other phases of sewage analysis.

Oxidation-reduction potential is not an abstract term borrowed from the realm of physical chemistry. It is a definite potential which may be measured directly in volts by means of a Wheatstone bridge, just as may a battery or any other electrical cell. The range of voltages met with in sewage treatment plants usually lies between +0.4 and —0.4 volts when referred to the standard hydrogen electrode.

The electrical measurement of this potential is based on a cell, or rather two half-cells, one half of which is the sewage and the other half a standard hydrogen electrode. The latter is the reference electrode whose potential is arbitrarily assumed as 0.0 volts. For practical purposes a standard calomel electrode is used and a correction factor of +0.28 volts applied because the potential of the calomel electrode is 0.28 volts higher than the standard hydrogen electrode.

In the everyday use of a pH meter the same procedure is adopted. A calomel electrode forms half the cell and a glass electrode is placed in the sewage to form the other half cell. In reality, the measurement of pH is a measurement of the oxidation-reduction potential existing from the difference in concentration of hydrogen ions in the sewage and in the standard hydrogen electrode.

It is not necessary to understand the mathematical relationship upon which this potential is based in order to apply it to practical uses. It is sufficient to state that the oxidation-reduction potential expresses a mathematical relationship between oxidants and reductants in the sewage. The higher the percentage of oxidants the more positive the potential; the higher the percentage of reductants the more negative the potential. This relationship has a direct practical significance in that positive potentials represent an aerobic or oxidizing environment while negative potentials represent an anaerobic or reducing environment.

The oxidation-reduction potential is a measure of the intensity of oxidation and not a quantitative measure of oxidizing or reducing capacity. The latter are measured by the concentration of oxidants and reductants. A direct parallel exists with the pH determination. The pH indicates the intensity of acidity or alkalinity but not the total of either available in the liquid. The quantitative measurements of acidity and alkalinity are necessary in order to determine the amounts of each present. Only as hydrogen or hydroxyl ions become dissociated do they influence the pH. Similarly, only as oxidants or reductants are dissolved and enter the molecular or ionic state do they exert their influence on the oxidation-reduction potential.

Oxidation and reduction must always be associated together. One of the fundamental laws of nature must be followed in all chemical reactions, namely, for every action there must be an equal and opposite reaction. Thus, for every oxidation there must be an equal and opposite reduction until a final state of equilibrium is attained between oxidants and reductants. In any oxidation-reduction reaction the oxidants are reduced and the reductants oxidized to approach equilibrium. These are the

fundamental reactions taking place in the relative stability test bottle, with the organic matter acting as reductants and the dissolved oxygen, nitrates, nitrites, sulphates, serving as oxidants.

When the aforementioned oxidants are exhausted aerobic conditions cease to exist in the sewage. The biological environment in the sewage then becomes anaerobic or septic in character, with consequent formation of odorous compounds. Thus, the relative stability test indicates the length of time aerobic conditions, or a positive oxidation-reduction potential will be maintained in the sewage during the course of biochemical oxidation of the organic reductants utilizing the oxidants such as dissolved oxygen, nitrates, nitrites, and sulphates present in the effluent at the time of a sampling.

By itself, the relative stability test has little practical significance. Taken literally, the test would indicate the length of time aerobic conditions would be maintained if no oxidants were added by the receiving stream and no absorption of oxygen took place from the atmosphere. These conditions do not ordinarily prevail in any natural stream. An exception is an ice-blanketed stream without side entry feeders.

As far as the operator is concerned, the relative stability test is useful in the routine operation of a secondary treatment plant as an index of performance. If the relative stability is high, indications are that sufficient oxidants are present in the effluent to take care of the oxidation of the organic matter without creating a nuisance in the stream. A low relative stability might possibly indicate either too much organic matter or too low a quantity of oxidants in the effluent if not enough dilution were provided by the stream. Final opinion on the quality of the effluent can only be based on its effect on the stream.

Effect of Nitrates in a Stream

Some engineers may still prefer the relative stability test to the B.O.D. test even though the former gives no quantitative measurements, because it does take into account the effect of nitrates in effluents. This brings up the question of the significance of nitrates in sewage plant effluents and in the receiving streams.

Consideration of oxidation-reduction potentials will reveal that if any dissolved oxygen is present in the stream, the potential will be positive to such an extent that most of the nitrates and other oxidants will not be utilized to furnish oxygen for the bacteria. Nitrates would only be utilized when the receiving stream affords such a limited dilution that essentially all of the dissolved oxygen is exhausted. In other words, the nitrates act as a last line of defense in preventing onsets of anaerobic conditions in the stream. When most of the nitrites, nitrates, sulphates, and similar oxidants are reduced, the oxidation-reduction potential is approximately zero and septic reduction of organic matter will begin, with the production of odors and other nuisances.

It is not sound engineering practice to depend on an effluent with a B.O.D. of such a value that conditions in the river are so close to becoming septic that the nitrates must furnish oxygen. Sewage treatment plants should be designed and operated in such a manner that a safety factor of some dissolved oxygen should always be present in the stream.

Where the preservation of fish life is the governing factor in streams, the dissolved oxygen should not be permitted to fall below 3 ppm. Then the presence of nitrates will have no effect inasmuch as the oxidation-reduction potential will be so high that the nitrates will not be reduced and thus will not furnish the oxygen for oxidation of the organic matter. The only possible effect on fish life might be an indirect one in that nitrates "fertilize" the water and aid algae growths. However, the disadvantage of algae growths stimulated by nitrates are so many that every attempt should be made to eliminate them wherever possible.

Proper Concepts of Stream Oxidation

As far as oxidation of organic matter in the stream is concerned, it makes no difference whether a plant effluent is low or high in nitrates, except when the stream is on the ragged edge of turning septic. It follows that it makes no difference whether the effluent is from a low or a high rate tricking filter plant or from an activated sludge plant providing a low or a high degree of nitrification. Regardless of the type of plant, all effluents should represent such a degree of treatment that the quantity of reductants or organic matter discharged into the stream will be low enough to permit an oxidizing environment to exist at all times according to the criterion established for stream condition.

The principal factors which govern whether this criterion will be met are the relative flows of effluent and stream, the reductants in the effluent, the oxidants in the stream or entering the stream through reaeration, and the relation between these reductants and oxidants. The concentration of reductants is indicated by the B.O.D. test which serves as the index of effluent quality. The concentration of oxidants in the stream is indicated by the dissolved oxygen test and serves as an index of the oxidizing capacity of the stream. The relation between reductants and oxidants as they exist in the stream is an index of the state of oxidation and is measured by the oxidation-reduction potential.

SLUDGE BULKING CONTROLLED BY CHLORINATION

By STEPHEN R. KIN

Sanitary Engineer, Camp Butner, N. C.

AT ONE of the Army activated sludge sewage treatment plants in the South, chlorination of return activated sludge was tried to correct a condition of sludge bulking which persisted for several months.

Conditions for sludge bulking were favorable, i.e., summer season, heavy sewage loading and blower trouble. One of the three blowers had been down for repairs a considerable part of the time. However, even with all three blowers in operation, dissolved oxygen could not be maintained at the outlet end of the aeration tanks at all periods.

Corrective measures taken to control the sludge bulking included idling of one or more of the aeration tanks, with occasional additions of sewage for several days, and reducing the solids concentration in the mixed liquor. At one time an effort was made to remove all of the activated sludge from the clarifiers and aeration tanks so that a new sludge could be built. Also, the by-passing of primary clarifier effluent to reduce the sewage load to the aeration units was tried. Some of the measures showed an improved sludge, but when this sludge was put into regular operation it, too, began to swell.

Return Sludge Chlorination Last Resort

Chlorination of the return sludge was started at a dosage of 10-16 ppm., based on return sludge flow. This high dosage, which appears even higher when the low suspended solids (700 ppm.) of the return sludge is considered, was expected to destroy the filamentous growths. Whether or not all of the activated sludge was destroyed did not matter, since it was planned to build a new sludge after the chlorination. It was thought that the previous effort to grow a new sludge may have failed because all of the activated sludge, especially the filamentous growths, could not be completely removed.

After about four days of chlorination, the sludge lifted over the final weirs only during the peak flows. By the end of about ten days, the bulking was completely controlled, the final effluent was clear, and the sludge had good settling properties. This was unexpected. There proved to be no further need of "building up a new sludge" as had been expected and planned on.

Chlorination was continued for an additional ten days, although at a lower rate. During this time no trouble was experienced in maintaining dissolved oxygen in the aeration tanks. Although during peak sewage loading, while only two blowers were in use, the dissolved oxygen would often drop below 0.5 ppm.

After this chlorination, it was not too difficult to maintain the sludge in good condition. However, from time to time it was necessary to again practice chlorination of the return sludge until "threatened bulking" had been checked and a controlled sludge had again been re-established.

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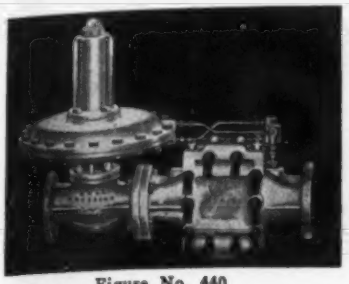

Figure No. 440

← THE NEW "VAREC" *Approved* PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

Unit consists of Diaphragm-operated Regulator, Flame Trap, and Thermal Shutoff Valve. Maintains a predetermined back pressure, passing surplus gas to Burner. Stops flame propagation. Patented telescopic flame trap element simplifies inspection and maintenance. Listed by the Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	2½"	3"	4"	6"
Sh. wt..	125	140	160	200	260

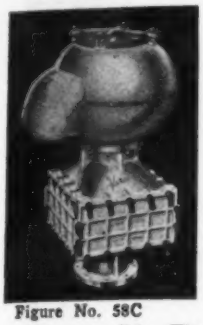

Figure No. 58C

"VAREC" *Approved* PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH ←FLAME ARRESTER

Installed on digesters and gas holder domes, it affords emergency Pressure and Vacuum Relief and prevents flame entrance from atmospheric disturbances. Equipped with extensible Flame Arresting element for easy inspection and maintenance. Pure aluminum. Non-corrosive. Listed by the Underwriters' Laboratories for Vent Lines in oil tanks. Sizes 2" to 10".

Sizes	2"	3"	4"	6"
Sh. wt.	70	105	160	225

"VAREC" *Approved* WASTE GAS BURNERS——→

Installed wherever disposal of surplus gas is a problem. Unit has adjustable air intake in the venturi tube, pilot valve adjustable from outside. Long, heavy cast iron draft stack insures proper draft and complete combustion.

Sizes	2"	3"	4"
Sh. wt.	450	480	500

Figure No. 236

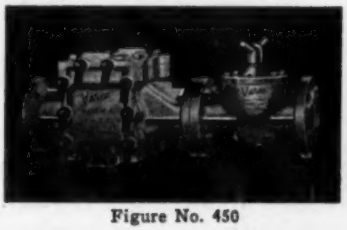

Figure No. 450

"VAREC" *Approved* FLAME TRAP ASSEMBLY

Flame Trap and Thermal Shutoff Valve. Unit self-contained, simple, foolproof. Installed in all gas lines supplying gas utilization equipment. No expensive fitting-up necessary. Arrests flame propagation. Easy inspection and maintenance. Aluminum and stainless steel. Non-corrosive. Flame Trap Element listed by Underwriters' Laboratories for vent lines in oil tanks.

Sizes	2"	2½"	3"	4"	6"
Sh. wt...	90	100	115	150	200

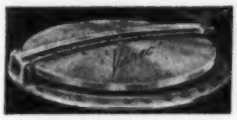

Figure No. 220A

"VREC" *Approved* MANHOLE COVERS

Installed on digester and gas holder domes, affords quick and easy access. Has square, graphite-impregnated, fire proof gasket. Nonsparking. Gas-tight.

Sizes	18"	20"
Sh. wt.	100	110

Figure No. 51A

"VAREC" *Approved* FLAME CHECK

Acid resisting. Union type fitting. Positive flame stop for small lines. Has five 40-mesh fire screens. Easy inspection and maintenance.

Sizes	½"	¾"	1"
Sh. wt.	10	10	10

Figure No. 216A

"VAREC" *Approved* MANOMETERS

Single or Triple tube. Open or push-button control types. Accurate. Aluminum housing. Bronze fittings. Pyrex glass. Automatic—Fireprpof—Safe. Sizes 6" to 36".

Sizes	9"	12"	15"
Sh. wt. 16	18	20	

Figure No. 387

"VAREC" *Approved* SENSITIVE PRESSURE (REDUCING) REGULATOR SINGLE PORT

Maintains upstream or downstream pressure to within 0.5" of water of predetermined pressure. Positive Shutoff. Aluminum body. Throttling type inner valve. 18-8 stainless steel trim. Sizes 2" to 6".

Sizes .	2"	2½"	3"	4"
Sh. wt.	110	115	140	175

Figure No. 211A

"VAREC" *Approved* BACK PRESSURE (REDUCING) CHECK VALVE

Installed in relatively low pressure gas lines. Prevents back-flow through meters. Non-chattering, non-pulsating, non-corrosive, non-sparking.

2"	3"	4"	6"
20	35	70	125

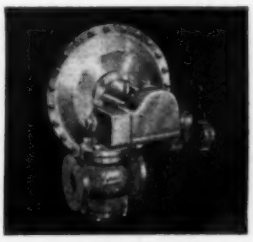

Figure No. 187

"VAREC" *Approved* SUPER SENSITIVE PRESSURE (REDUCING) REGULATOR DOUBLE PORT

Maintains upstream or downstream pressure to within 0.2" of water of predetermined pressure. Standard working parts 18-8 stainless steel with synthetic rubber diaphragm. Non-corrosive. Sizes ½" to 10".

2"	2½"	3"	4"	6"
190	200	233	260	350

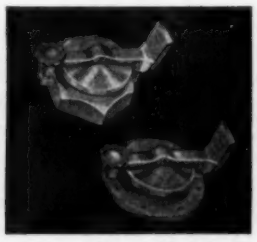

Figure Nos. 48 and 42A

"VAREC" *Approved* SAMPLING HATCH COVERS

For use on digester domes. Available in several combinations of materials. Non-corrosive, gas-tight, self-closing, spark-proof. Figure 42A Flanged and Figure 48 Screwed.

4"	6"	8"	10"
12	17	23.	27

Figure No. 232D

"VAREC" *Approved* SEDIMENT TRAP AND CONDENSATE DRIP TRAP ASSEMBLY

Cast iron construction. 18-8 stainless steel working parts. Hand operated or automatic. Sizes 2"-2½"-3"-4".

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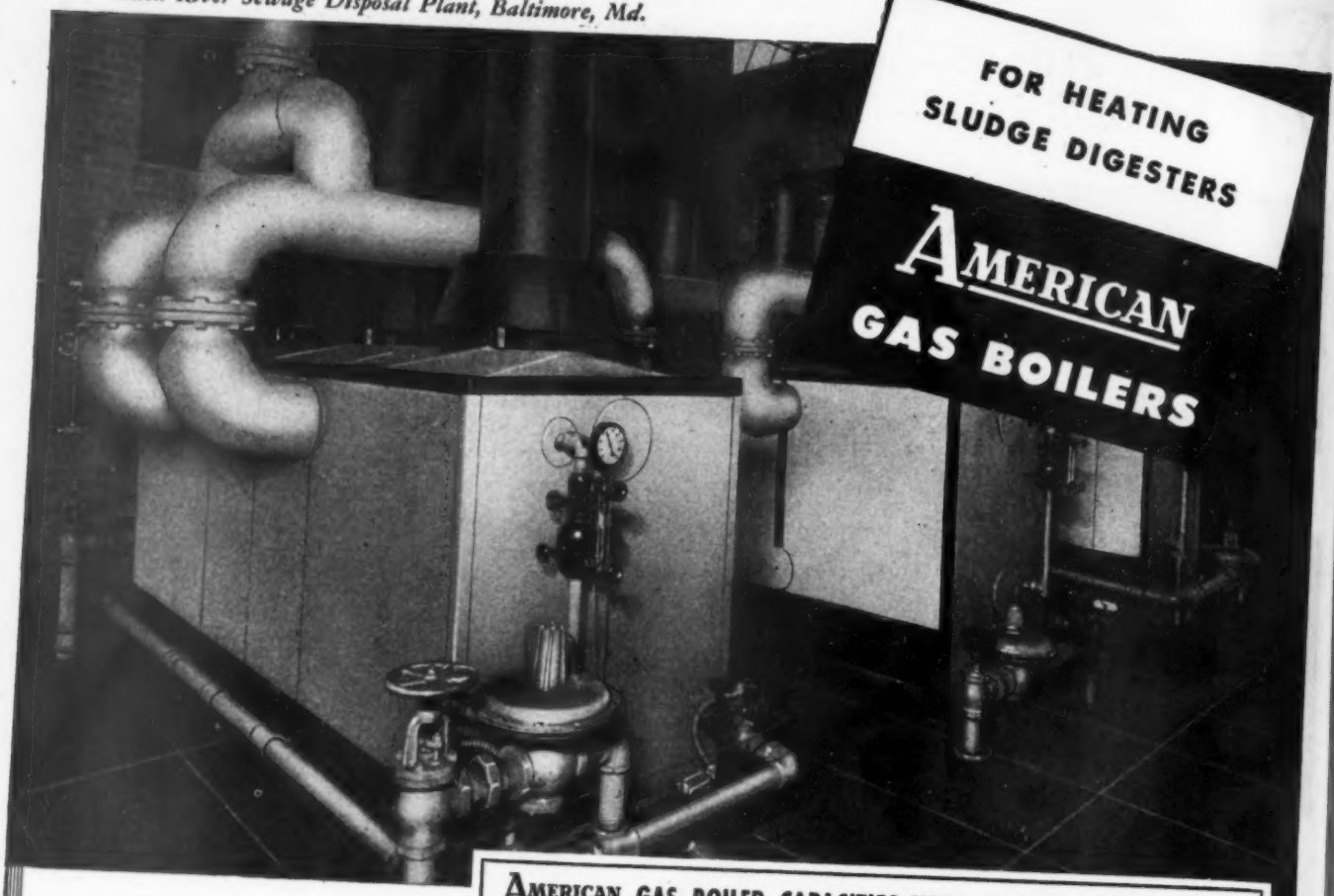

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American GAS BOILER CAPACITIES WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU. per Hour	Cu.Ft. 700 BTU. Sludge Gas	Over-all Hgt xx	Floor Space	
								Width Front	Depth
.....	1-GA-4E	31,500	....	210	39,350	56	40½"	16"	20½"
.....	1-GA-5E	42,000	....	280	52,500	75	40½	16	23½
.....	1-GA-6E	52,500	....	350	65,600	94	40½	16	26½
.....	2-GA-4E	63,000	....	420	78,750	113	50½	16	23¼
.....	2-GA-5E	84,000	....	560	105,000	150	50½	16	26¼
.....	2-GA-6E	105,000	....	700	131,200	188	50½	16	29¼
.....	2-GA-7E	126,000	....	840	157,500	225	50½	16	32¼
.....	4-GA-8E	147,000	....	980	183,750	263	54	16	37¼
.....	4-GA-9E	168,000	....	1120	210,000	300	54½	16	40¼
.....	4-GA-11E	210,000	....	1400	262,500	375	54½	16	46¼
.....	4-GA-13E	252,000	....	1680	315,000	450	56	16	52¼
0-GS-4E	.....	61,200	255	.....	76,600	109	52¼	16	33¼
0-GS-5E	.....	81,600	340	.....	102,000	146	53	16	37¼
0-GS-6E	.....	102,000	425	.....	127,500	182	52½	16	41¼
0-GS-7E	.....	122,000	510	.....	153,000	218	53¾	16	45
1-GS-4	1-GW-4	146,000	610	980	182,500	261	54½	35*	33¼
1-GS-5	1-GW-5	186,000	775	1240	232,500	332	56¾	39*	33¼
1-GS-6	1-GW-6	225,000	940	1500	281,500	402	56½	43*	33¼
1-GS-7	1-GW-7	265,000	1105	1770	331,000	473	57	47*	33¼
1-GS-8	1-GW-8	305,000	1270	2030	381,000	545	59¼	51*	33¼
1-GS-9	1-GW-9	345,000	1435	2300	431,000	616	58½	55*	33¼
1-GS-10	1-GW-10	384,000	1600	2560	480,000	686	59¼	59*	33¼
1-GS-11	1-GW-11	424,000	1765	2820	530,000	757	59	63*	33¼
4-GS-6	4-GW-6	480,000	2000	3200	600,000	857	74	53	52
4-GS-7	4-GW-7	576,000	2400	3840	722,000	1030	75	58	52
4-GS-8	4-GW-8	672,000	2800	4480	840,000	1200	77	62	52
4-GS-9	4-GW-9	768,000	3200	5120	960,000	1372	77¾	66	52
4-GS-10	4-GW-10	864,000	3600	5760	1,079,000	1543	79½	70	52
4-GS-11	4-GW-11	960,000	4000	6400	1,200,000	1715	80	74	52
4-GS-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	75	85	64
4-GS-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	77	93	64
4-GS-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	77¾	103	64
4-GS-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	79½	107	64
4-GS-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	80	110	64
4-GS-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	77	136	64
4-GS-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	77¾	148	64
4-GS-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	79½	160	64
4-GS-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	80	172	64
4-GS-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	77¾	186	64
4-GS-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	79½	202	64
4-GS-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	80	218	64

*1-GS shown. The 1-GW is 4" shorter xx To top of Draft Hood

SEWAGE SLUDGE DIGESTION TANK HEATING

Some Theoretical and Practical Considerations in Design and Operation

By NORMAN C. WITTWER
Consulting Sanitary Engineer
Trenton, N. J.

THE artificial maintenance of optimum temperatures in sludge digestion tanks has become standard practice in sewage treatment plant design and operation in the northern portion of the United States, and in other localities subject to adverse climatic conditions. Experience has shown that the lowering of the temperature of digesting sludge in unheated or improperly heated digestion tanks during the winter months seriously reduces biological activity, thus contributing greatly to the operating problems inherent in sewage sludge digestion.

Most engineers and sewage treatment plant operators have reached the conclusion that digestion tank temperatures of from 80° F. to 90° F. are most satisfactory, both as to results obtained, and as to economy of heating and heat exchange. Some plants keep the temperature of digesting sludge well above 90° F., but this practice is the exception rather than the rule. The writer's experience with temperatures at or about 85° F. has, on the whole, been very satisfactory, and there seems to be very little justification for maintaining temperatures above this level. On the other hand, as temperatures drop below 80° F., the digestion of sludge is gradually retarded. When the temperature drops below 70° F., active digestion ceases almost completely, and the sludge lies dormant until the proper temperature environment is reestablished. The absence of proper temperature environment in the digestion compartments of Imhoff tanks explains in part some of the difficulties which have always been encountered with these units.

Proper Design Voids Most Operating Problems

The problem of providing heat for sludge digestion purposes is largely one of original design, although it becomes necessary at times to install heating facilities at existing plants. Usually, heat exchange equipment installed after a plant has been placed into operation is more or less a make-shift arrangement, and is not nearly so effective or economical as would be a heating system properly designed and installed at the time the plant was constructed. The responsibility for successful sludge digestion rests primarily with the designing engineer. If he realizes the importance of properly designed sludge heating, future operating troubles due to ineffective sludge digestion will be reduced to a minimum.

The technical solution of sludge digestion tank heating problems involves the same fundamental technique used in the solution of other heating and heat transmission problems. However, there has been some tendency on the part of sanitary engineers to ignore such fundamentals, and to use instead certain empirical formulae or values for the determination of the over-all heating requirements of sludge digestion tanks. These formulae or values have not been adequately substantiated by scientific study and experimentation for all of the varying types of construction and conditions met with in ordinary practice, and the indiscriminate use of such methods has naturally resulted in some plant installations which have been deficient in heating capacity or heat exchange, or which have been over-designed.

However, the careful designer will treat each heating application as an individual problem, involving a consideration of climate, digestion tank construction and exposure, all heat losses through the structure, fresh sludge quantities, and proper type of heat exchange equipment. When broken down into its component parts, the solution of such a problem becomes quite simple, involving only a rudimentary knowledge of the fundamentals of heat transmission.

This discussion will present the subject matter in the same order as would ordinarily be used in the solution of a practical problem in sludge digestion tank heating. Fundamental theory and illustrative problems will be given concurrently for each of the major considerations involved. These are:

1. Heat losses from a sludge digestion tank, involving the determination of heat losses from a heated liquid sludge mass to air or ground through the exposed structural components of the tank.
2. Heat required to raise the temperature of the additions of fresh sludge to the temperature of digesting sludge in a sludge digestion tank.
3. A consideration of methods for applying heat to the contents of a sludge digestion tank.
4. Theory of heat transmission as applied to heat exchangers, and design applications.
5. Selection of heating equipment.

HEAT LOSSES FROM A SLUDGE DIGESTION TANK

Methods of Heat Transfer

Heat transmission (or heat losses) between the mediums on two sides of a wall, roof, or floor takes place by three methods, namely, radiation, convection, and conduction. These methods of heat transfer may be defined as follows:

Radiation is the transmission of heat through space by wave motion in a manner similar to the travel of light waves.

Convection of heat occurs in fluids (liquids or gases), and is the transfer of heat accomplished by the motion of the fluid from a locality where it receives heat to a locality where it gives up heat. The motion of the fluid is usually the result of differences in density caused by temperature differences. This is called free convection. If the motion is produced by some mechanical means, such as a stirrer, or a circulating pump, it is called forced convection.

Conduction is the transfer of heat from one part of a continuous material to another part of the same material, or from

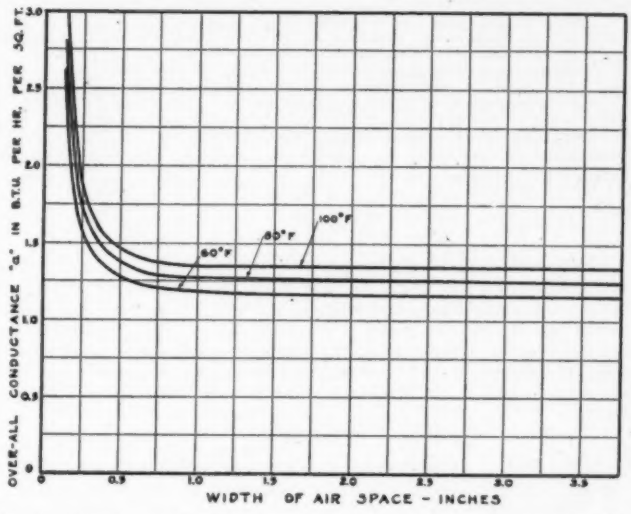

Fig. 1. Air Space Conductances at Several Mean Temperatures

one material to another in physical contact with it, without appreciable movement of the particles of the material.

In most cases the actual transfer of heat is accomplished by more than one of the above defined methods. It is therefore preferable to use other terms, such as "transfer," or "transmission," or "conductance," to describe an over-all heat transfer process, reserving the use of the terms "radiation," "convection," and "conduction" for that fraction of the total heat transfer accomplished by the mechanism designated.

For example, consider a wall constructed of one thickness of concrete, an air space, and a second thickness of brick masonry with air on both sides of the composite wall, and with the concrete being adjacent to the warmer air. Heat will be received by the concrete surface from the inside air by radiation, convection and conduction. It will be carried through the homogeneous concrete section by conduction, and carried across to the opposite brick wall surface through the air space by radiation, convection and conduction. From here it will be carried by conduction through the homogeneous brick section to the outer surface of the wall, and will leave this surface by radiation, conduction and convection.

Any digestion tank wall, roof, floating cover, gas dome or bottom floor may be divided into internal and external surfaces, homogeneous materials, and interior air or gas spaces, as the

case may be. Practical heat transmission coefficients have been determined experimentally which will give the total heat transferred through any of these component parts of a structure, and if the method of applying these individual coefficients is thoroughly understood, it is a simple matter to calculate the over-all heat transmission or heat losses through any combination of materials.

Notation Used in Heat Loss Formulae

k = Thermal conductivity of a homogeneous material 1-inch thick, in B.t.u./hr./sq. ft./1° F. difference in temperature between the two surfaces of the material.

f = Film or surface conductance; the amount of heat expressed in B.t.u./hr./sq. ft./1° F. temperature difference transmitted by convection or conduction from a fluid to a surface with which it is in contact, or vice versa, from a surface to the fluid surrounding it.

f_i = coefficient of heat transfer *to* the inner or warm surface.

f_o = coefficient of heat transfer *from* the outer or cold surface.

a = Thermal conductance of an air or gas space in B.t.u./hr./sq. ft./1° F. temperature difference.

U = Thermal conductance or over-all coefficient of heat transmission; the amount of heat transmitted in B.t.u./hr./sq. ft./1° F. difference in temperature between the warm and cold sides of a wall, roof or floor.

H = Total heat loss in B.t.u./hr. transmitted through any material, or any combination of materials, such as a wall, roof, cover, or floor of a sludge digestion tank for the total area involved.

A = Area of a surface in square feet as actually measured from the plans or from the structure. Use the net inside or heated dimensions.

T_i = Temperature in °F. of the medium adjacent to the inside or warmer surface; the inside temperature.

T_o = Temperature in °F. of the medium adjacent to the outside or colder surface; the outside temperature.

b = Thickness in inches of homogeneous materials.

Heat Flow by Conduction

The flow of heat through a homogeneous material by conduction is proportional to

(a) the thermal conductivity of the material.
(b) the difference in temperature between the two surfaces or planes considered.
(c) the area through which the heat flows.
and (d) inversely proportional to the distance between the two surfaces or planes considered.

Thus, the total heat transferred between two surfaces of a homogeneous material by conduction can be expressed by the following formula:

$$H = \frac{A\,k\,(T_i - T_o)}{b} \qquad \ldots\ldots (1)$$

The coefficients of thermal conductivity given below in Table 1 for homogeneous materials are average values, and have been shown by numerous experiments to be accurate for the typical materials described. Since the conductivity of a material has been found to depend upon its composition, texture and density, these coefficients should not be used for other variations of these materials. Other coefficients can be found in standard reference works.

TABLE 1.

THERMAL CONDUCTIVITY COEFFICIENTS "K"

For Homogeneous Materials (1" Thick) in B.t.u./hr./sq. ft./°F.

Material	k
Cement mortar	12.00
Brickwork, low density	5.00
Brickwork, high density	9.20
Concrete, typical stone structural	12.00
Stone masonry	12.50
Wood, average value for ordinary woods	1.00
Asphalt or tar composition roofing	6.50*
Wrought iron	370.
Steel (1% C)	314.
Pure copper	2640.
Water	4.10

*For thickness used on typical roof construction, not per 1-inch of thickness.

Film Conductance

When gaseous fluids such as air or sewage gas are in contact with solids, heat will flow from the warmer to the colder material. The method of heat transfer is principally a combination of convection and conduction. However, the condition of the air or gas has a very important influence on the rate and mode of heat transfer. It is certain that in all cases a stationary film of air or gas is present on the surface of the solid material, separating the solid from the main body of air or gas. The thickness of this film depends upon its temperature, and upon the velocity of the air or gas parallel to the solid surface.

Therefore, heat transfer through an air or gas film has been found to proceed at a higher rate where movement or velocity exists than is the case for still air. This is illustrated by the film coefficients in common use by engineers for general heating practice. These coefficients are not for convection alone, or for conduction alone, but are experimental, combination over-all film coefficients for heat transfer from a wall surface to or from the main body of adjacent air. They are as follows:

f_i = 1.65 B.t.u./hr./sq. ft. for inside air without appreciable motion or velocity.

f_o = 6.00 B.t.u./hr./sq. ft. for outside air with a velocity of 15 miles per hour or higher.

The above coefficients are sufficiently accurate for air or gas film conductance as it exists on the inside and exterior surfaces of sludge digestion tank structures, and will be used throughout this discussion. They will be applied to sewage gas (approx. 30 per cent CO_2 and 70 per cent CH_4) as well as to atmospheric air.

Where liquids are in contact with a structure through which heat transmission takes place, film resistance is also present between the surface of the structure and the main body of the liquid. However, as will be explained in some detail later on in connection with the discussion on heat exchangers, the film coefficient is influenced to a large degree by the motion of the liquid. Where temperature differences between liquid and wall surface are small, natural or free convection will be slight, and very little motion of the liquid adjacent to the walls of a digestion tank will be present. Therefore for practical purposes, both the liquid contents of a tank, and the dry or wet earth surrounding the tank, are assumed to be always in direct contact with the structure, without an intermediate film. However, where either dry or wet earth is in contact with the exposed, cold side of the structure, a certain amount of resistance to the transmission of heat is present. While not strictly film resistance, such resistance is of some significance. Therefore, the coefficients for heat transfer from wall surfaces into earth are included in Table 2.

TABLE 2.

FILM COEFFICIENTS "F"

(B.t.u./hr./sq. ft. °F.)

	k
Concrete to or from still air	1.65
Concrete to outside moving air (15 mi. per hr.)	6.00
Brickwork to or from still air	1.65
Brickwork to outside moving air (15 mi. per hr.)	6.00
Steel to or from still air	1.00
Steel to outside moving air (15 mi. per hr.)	3.00
Composition roofing to outside moving air	10.50
Concrete to dry earth	1.00
Concrete to wet earth or to water	2.00

Air and Gas Spaces

Heat is carried across an air or gas space by a combination of radiation, convection or conduction. A large part of the heat transferred across an air space bounded by ordinary building materials such as wood, plaster, concrete, etc., is by radiation. The effect of heat radiation can be greatly reduced by facing the air spaces with metallic surfaces such as aluminum foil, coated sheet steel, or other low-emissivity, infra-red reflective metal surfaces, thus causing a major portion of the heat to be transmitted by convection. In sludge digestion tank construction, only ordinary building materials are customarily used, and we are therefore concerned only with air spaces bounded by such materials, without reflective surfaces.

It has been found as the result of experiments conducted at the University of Minnesota under a cooperative research agreement with the American Society of Heating and Ventilating Engineers that the over-all thermal conductances across air spaces between ordinary building materials are fairly uniform at a given mean temperature for widths of air space in excess of ¾-inch. This is illustrated by Figure 1, in which curves for several mean temperatures show the relationship between widths of vertical air spaces and over-all surface to surface conductances.

From these curves, an average conductance value of 1.25 B.t.u /hr./sq. ft./1° F. temperature difference is established for vertical air spaces ¾-inch or more in width, and for the temperatures ordinarily encountered in sewage sludge digestion practice. When air spaces are not faced with reflective insulating materials, the difference between upward heat flow through single horizontal or sloping air spaces and through single vertical air spaces is comparatively small for the same temperature difference. Therefore, the same conductance value of 1.25 will be used for all air and gas spaces found in sludge digestion tank construction, whether they be vertical or horizontal.

Resistance Concept

It is obvious from the above discussion of heat transmission that the higher the thermal conductivity or over-all conductance of a material or combination of materials, the lower is its resistance to the flow of heat. Thus, the resistance to the flow of heat is inversely proportional to the thermal conductivity or conductance. If R is used to designate over-all resistance, and r_1,

r_2, etc., are used to designate unit resistances, then the over-all resistance to the flow of heat through a structure will be

$$R = r_1 + r_2 + \ldots\ldots + r_n \quad \ldots\ldots (2)$$

If Equation (2) is applied to a wall built up of a single homogeneous material b inches thick, then

$$\frac{1}{U} = \frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o} \quad \ldots\ldots (3)$$

where $\frac{1}{U} = R$ = over-all resistance.

$\frac{1}{f_i} = r_1$ = inside film resistance.

$\frac{1}{f_o} = r_n$ = outside film resistance.

$\frac{b}{k} = r_2$ = internal resistance to heat transfer by conduction.

For a compound wall built up of two homogeneous materials having thicknesses b_1-inches and b_2-inches, and conductivity coefficients k_1 and k_2 respectively, separated to form an air space of conductance a, and with both sides of the wall exposed to air, the over-all resistance will be

$$\frac{1}{U} = \frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{1}{f_o} \quad \ldots\ldots (4)$$

where $\frac{1}{a}$ = air or gas space resistance. The over-all coefficient of heat transmission U then becomes

$$U = \frac{1}{\frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{1}{f_o}} \quad \ldots\ldots (5)$$

If the inside air is replaced with water then $\frac{1}{f_i}$ in Equations (4) and (5) becomes zero.

Heat Loss Formulae

Referring back to Equation (1), the same relation exists for a compound wall as is the case for a single homogeneous material. Therefore, the total heat loss between two surfaces of any structure can be expressed by

$$H = A\ U\ (T_i - T_o) \quad \ldots\ldots (6)$$

If the proper value for U is substituted in Equation (6), as for example the U in Equation (5), then the total heat loss H becomes,

$$H = \frac{A\ (T_i - T_o)}{\frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{1}{f_o}} \quad \ldots\ldots (7)$$

Equation (7) is the fundamental formula for the total heat loss through any material or combination of materials. In applying this formula, it should be remembered that each material in a compound wall, roof or floor will have a different coefficient k, and that there will be as many values of $\frac{b}{K}$ as there are different materials.

Computation of Sludge Digestion Tank Heat Losses

The following problem will illustrate how the fundamental formulae and heat flow coefficients may be applied to the determination of heat losses from sludge digestion tanks. A common type of construction will be shown, and the method used in solving this problem can be extended to almost any type of digestion tank design. Since all such calculations are at the best only approximate, the slide rule will be used throughout.

Illustrative Problem 1.

Calculate the total heat loss, in B.t.u. per hour, for the sludge digestion tank shown in Figure 2. The inside sludge temperature will be 85° F.; the minimum sustained winter air temperature is estimated at 15° F.; the minimum sustained dry earth temperature at 40° F.; and the minimum sustained wet earth temperature at 50° F. For the purpose of this computation, heat losses from the scum-covered annular ring of water surface between the floating cover and the tank walls will be ignored, as this loss will be very small, and will be more than compensated for by assuming the diameter of the floating cover to be equal to the inside diameter of the tank.

The total heat loss will be the sum of the individual losses through the tank floor, the several vertical sections of the wall,

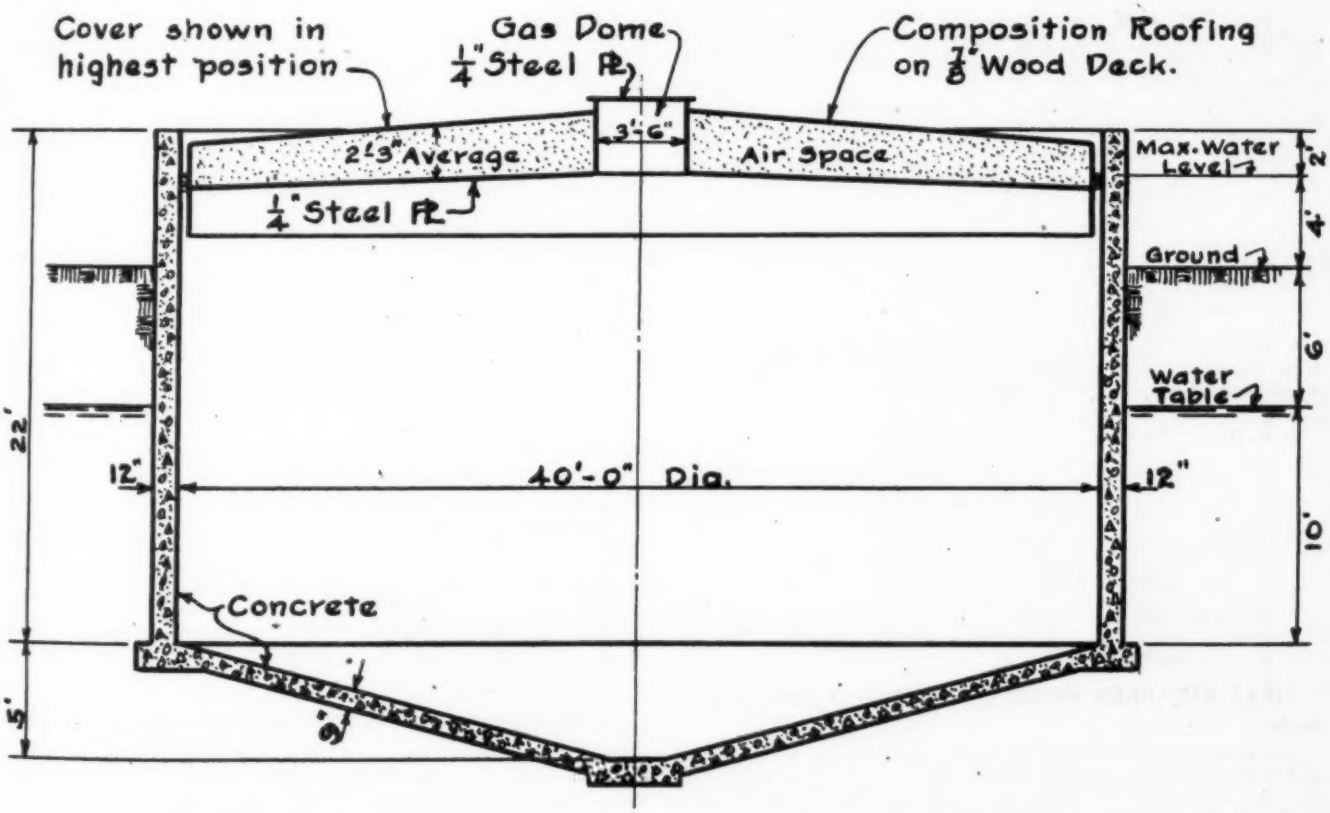

Fig. 2. Typical Sludge Digestion Tank with Floating Cover

and the floating cover. As stated above, where inside water or sludge is in direct contact with the structure, the resistance $\frac{1}{f_i}$ will be zero.

Solution

1. Heat loss H_1 through the tank floor. This involves only the heat transfer through the 9-inch thick concrete slab, and from the bottom of the slab into the wet earth.

$$H_1 = \frac{A\ (T_i - T_o)}{\frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o}}$$

$$= \frac{1290 \text{ sq. ft. } (85 - 50)}{0 + \frac{9}{12.00} + \frac{1}{2.00}}$$

$$= 36{,}200 \text{ B.t.u./hr.}$$

2. Heat loss H_2 through portion of wall below ground water table. This calculation is similar to that for H_1.

$$H_2 = \frac{1260 \text{ sq. ft. } (85 - 50)}{0 + \frac{12}{12.00} + \frac{1}{2.00}}$$

$$= 29{,}400 \text{ B.t.u./hr.}$$

3. Heat loss H_3 through portion of wall between ground water table and ground surface. This calculation is similar to that for H_1, except that heat is transferred into dry earth instead of into wet earth.

$$H_3 = \frac{755 \text{ sq. ft. } (85 - 40)}{0 + \frac{12}{12.00} + \frac{1}{1.00}}$$

$$= 17{,}000 \text{ B.t.u./hr.}$$

4. Heat loss H_4 through portion of wall exposed to outside air. This calculation involves the use of the common film coefficient from concrete to outside air. Otherwise, the method is the same as for H_1.

$$H_4 = \frac{502 \text{ sq. ft. } (85 - 15)}{0 + \frac{12}{12.00} + \frac{1}{6.00}}$$

$$= 30{,}000 \text{ B.t.u./hr.}$$

5. Heat loss H_5 through gas dome. This calculation involves the transfer of heat across the gas space, through the inside gas film, through the very high conductance of the steel plate and through the outside air film. It is evident that the resistance to the transfer of heat which is offered by the steel plate could be ignored without affecting the slide-rule result.

$$H_5 = \frac{A\ (T_i - T_o)}{\frac{1}{a} + \frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o}}$$

$$= \frac{10 \text{ sq. ft. } (85 - 15)}{\frac{1}{1.25} + \frac{1}{1.65} + \frac{0.25}{314} + \frac{1}{6.00}}$$

$$= 500 \text{ B.t.u./hr.}$$

6. Heat loss H_6 through floating cover, diameter taken as 40 feet. Four layers of material are involved, namely, steel, air, wood deck, and composition roofing.

$$H_6 = \frac{A\ (T_i - T_o)}{\frac{1}{f_i} + \frac{b_1}{k_1} + \frac{1}{a} + \frac{b_2}{k_2} + \frac{b_3}{k_3} + \frac{1}{f_o}}$$

$$= \frac{(1260 - 10) \text{ sq. ft. } \times (85 - 15)}{0 + \frac{0.25}{314} + \frac{1}{1.25} + \frac{0.875}{1.00} + \frac{1}{6.50} + \frac{1}{6.00}}$$

$$= 43{,}800 \text{ B.t.u./hr.}$$

7. The total heat loss becomes—

$$H_t = H_1 + H_2 + H_3 + H_4 + H_5 + H_6$$
$$= 156{,}900 \text{ B.t.u./hr.}$$

HEAT REQUIRED BY FRESH SLUDGE ADDITIONS

Method

The heat required to raise the temperature of the fresh sludge additions to the temperature of the mass of digesting sludge in the tank is obtained by a simple calculation. For practical purposes, one B.t.u. is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Sludge has approximately the same characteristics as has water. Therefore the

$$\text{Heat required} = \frac{W\ (T_s - T_i)}{24} = \text{B.t.u./hr.} \quad \ldots\ldots\ldots\ldots\ (8)$$

where

W = Weight in pounds per day of fresh sludge additions.
T_s = Temperature in °F. of fresh sludge, ordinarily the same as the sewage flowing through the plant.
T_i = Temperature in °F. of the digesting sludge in the digestion tank.

Quantity of Fresh Sludge Additions

A sewage treatment plant which has been in operation for some time should have available a back-log of operating records which will indicate the average daily volume of liquid sludge additions to the digestion system. Wherever possible, such records should be utilized in the calculation of digestion tank heating requirements. Where such records are not available, or in the case of a new plant design, the engineer must carefully estimate the probable quantities of fresh sludge to be expected, basing the estimate on his own experience, or on the experience of others.

The quantity of fresh sludge added to a sludge digestion tank is influenced by the character of the sewage, the type of sewage treatment process, the method of plant operation, and also to a large extent by the degree of care exercised by the plant operators in limiting fresh sludge pumpings to the thicker, more concentrated liquid. Obviously, the addition of large quantities of excess water to the sludge digestion tank may not only overtax the heating facilities, but may also seriously interfere with the normal functioning of the sludge digestion processes.

The average daily quantities of fresh sludge solids to be expected at different types of sewage treatment plants are shown in Table 3. These quantities are for domestic sewage, without an appreciable proportion of industrial wastes, and without storm water drainage. In using these average figures for design, some allowance should be made for higher-than-average rates which may be sustained over periods of time long enough to influence over-all heat requirements. The writer believes that an increase of 20 per cent above these values provides a safe allowance for all practical purposes, unless more definite information is available.

TABLE 3
AVERAGE DAILY QUANTITIES OF FRESH LIQUID SOLIDS ADDED TO SLUDGE DIGESTION TANKS

	Average Moisture	Sludge to Digester, cu. ft./day/capita		
	%	High	Aver.	Low
Primary Treatment Plants	95	.070	.050	.035
Chemical Precipitation Plants..	92.5	.125	.085	.070
Trickling Filter Plants*	94	.080	.060	.045
Activated Sludge Plants	98.5	.280	.150	.100

*Including Humus Tanks.

Illustrative Problem 2.

Calculate the heat required by the fresh sludge additions to the sludge digestion tank shown in Problem 1. This tank forms part of a primary sewage treatment plant, and is designed for 16,000 persons at 3 cu. ft. per capita. The minimum sustained fresh sludge temperature T_s is expected to be 45° F. From Problem 1, $T_i = 85°$ F.

Solution

The average daily quantity of fresh sludge additions is estimated from Table 3 at .050 cu. ft./day.

$$W = .050 \times 16{,}000 \times 62.5 \times 1.20\% = 60{,}000 \text{ lbs./day}$$

$$\text{In Equation (8), heat required} = \frac{60{,}000\ (85 - 45)}{24}$$

$$= 100{,}000 \text{ B.t.u./hr.}$$

Total Heat Required

It can be seen by the foregoing discussion that the total heat required for a sludge digestion tank is the sum of heat required to compensate for the heat losses from the liquid through the walls, roof and floor of the tank, and the heat required to raise the temperature of the incoming fresh sludge to the temperature of the digesting sludge. Thus, for the digestion tank of Problems 1 and 2, the total heat required will be

Heat loss through structure..	=	156,900 B.t.u./hr.
Heat required for fresh sludge	=	100,000 B.t.u./hr.
Total heat required		256,900 B.t.u./hr.

METHODS FOR HEATING SLUDGE DIGESTION TANKS

Having determined the total heat requirements for a sludge digestion tank, the final element which enters into the thermal design of its heating system is the selection and calculation of an adequate heat exchange system. Several methods may be used for transferring heat into the liquid contents of a tank.

However, some methods, such as the use of steam or hot air in heating coils, are inapplicable to this type of problem since the resulting high temperature of the heat exchangers would be too conducive to scale formation. The methods worthy of our consideration are as follows:

1. Circulation of hot water through horizontal pipes placed around the inside periphery of a tank.
2. Circulation of hot water through vertical banks of heating pipes suspended in the liquid.
3. Direct introduction of hot water.
4. Preheating the fresh sludge before it is added to a tank.

Circulation of Hot Water Through Horizontal Pipes.—This is the most common method of transferring heat into a sludge digestion tank. The usual arrangement is to install the heating piping in the form of a spiral coil around the inside periphery of the tank as shown by Figure 3.

The spacing of the successive turns of the coil is usually about 12 inches. Hot water is admitted to the top of the coil and the colder return water is taken away from the lowest point.

In some instances, heating coils have been placed at or very near the floor of the tank. This practice is not too good because it tends to keep the more thoroughly digested sludge at a high temperature while the actively digesting sludge higher up in the tank receives only the benefit of somewhat lower temperatures. The most favorable location for the heating coil seems to be from a level about 6 ft. above the floor to a level not above the middle of the tank. This range usually covers the region of active sludge digestion.

Circulation of Hot Water Through Vertical Banks of Pipes.—Another common type of heat exchanger for digestion tanks with fixed roofs or covers is the vertical, multiple-bank type suspended from the roof. This type of heat exchanger is, or should be, removable from above. The vertical pipes are in series and are placed very close together, from 5 to 7 inches on centers. This type of heat exchanger is illustrated in Figure 4.

The hot water supply is introduced into the top of the first pipe, and is forced down and up through succeeding pipes until it is removed from the top of the last pipe. Such a unit should be located at or near the center of a small tank; while several units, distributed uniformly, should be used in larger tanks.

Direct Introduction of Hot Water.—The practice of introducing hot water directly into a digestion tank is of German origin, and up-to-date has not found much favor in this country. Several installations have been reported, but not much data as to their efficiency is available.

Keefer[3] found at Baltimore in comparative plant-scale tests that more heat was required to heat the sludge by the direct addition of hot water than was the case with well designed heat exchangers using circulated hot water. He claims, however, that the cost of constructing a pipe coil and return piping to the heating plant is saved; also since water at considerable pressure is generally available, it can be added directly to the tank without the use of pumps, whereas hot water circulating through the pipe coils must be pumped. But it must be remembered that the direct connection of a high pressure water supply, if potable, constitutes a cross-connection which is distinctly contrary to standard sanitary practice and health codes. Furthermore, the actual pumping of circulated water is a minor operation, involving very small pumps and low operating costs.

Downes[3], on the other hand, asserts that the practice of introducing hot water directly into the sludge contents of a digestion tank is detrimental as it tends to segregate grit and coarse particles such as seeds and inorganic materials from the sludge mass, thus accelerating accumulations of such materials in the bottom of the tank.

It is the writer's opinion that the objections to the direct addition of previously heated water more than outweigh the doubtful economy in first cost. Where outside water is used, the cost of purchase is in itself a continuing expense. In addition to the objections cited by Downes, the continuous introduction of hot water into the tank tends to thin out the sludge, thus reducing the amount of space available for digestion purposes. Naturally, there is a concurrent interference with sludge concentration, which is exactly the reverse of the above procedure.

Preheating the Fresh Sludge.—This method has been tried at a few plants. While not much operating data is available, it seems to the writer that the preheating of fresh undigested sludge would introduce an entirely new set of difficulties, not the least of which would be continuous sludge encrustation on the outside or inside of any heat exchanger used. This is due to the fact that the fresh sludge would necessarily have to be heated to a temperature considerably higher than the tank temperatures because it would be necessary to overcome all heat losses from the structure in addition to the mere raising of the fresh sludge to the temperature of the digesting sludge.

More experience with this method of heat exchange may ultimately demonstrate its fitness, both as to economy and operating effectiveness.

SLUDGE DIGESTION TANK HEAT EXCHANGERS

The theory involved in heat transfer from hot water circulated through spiral pipe coils around the inside of a digestion tank is quite similar to that involved in heat transfer from hot water circulated through banks of pipes suspended vertically into the liquid contents of a tank. Both types of heat exchangers involve a consideration of fluid motion, and of heat transfer by convection and conduction. As will be shown, the resistance in thin walled pipes and tubing to heat transfer by conduction is often much less than the resistance through the fluid films immediately in contact with the pipe walls. Film resistance is to a large extent influenced by convection, although the actual passage of heat through such a film is principally by conduction.

Consider the case of a fluid in contact with the wall of a pipe whose temperature is lower than that of the fluid, as shown by the left-hand portion of Figure 5. Although the main body of the fluid passing through the pipe may or may not be in turbulent motion, the thin film of fluid in contact with the pipe is relatively stagnant as the result of friction with the wall. The thickness of this stagnant film is not clearly defined and varies as the degree of turbulence of the passing fluid. Since the heat is transferred through this film largely by conduction rather than by convection, the entire process by which heat is transferred to the surface of the pipe from the main body of the fluid is somewhat complicated. Calculations are simplified, however, by the use of so-called *convection coefficients* which include the combined effect of both conduction and convection.

For digestion tank heating with pipe heat exchangers, it is

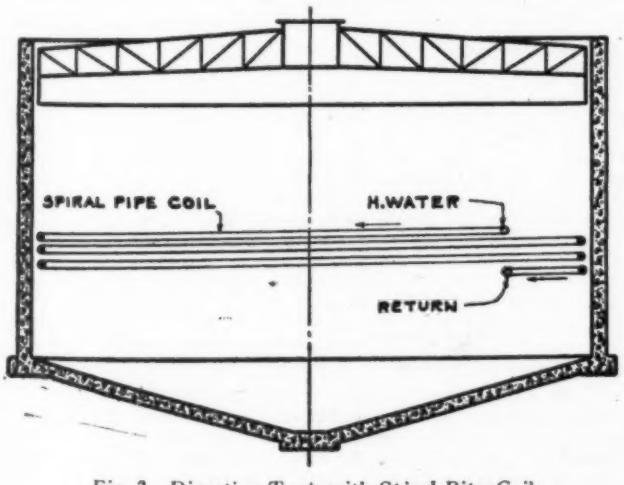

Fig. 3. Digestion Tank with Spiral Pipe Coil

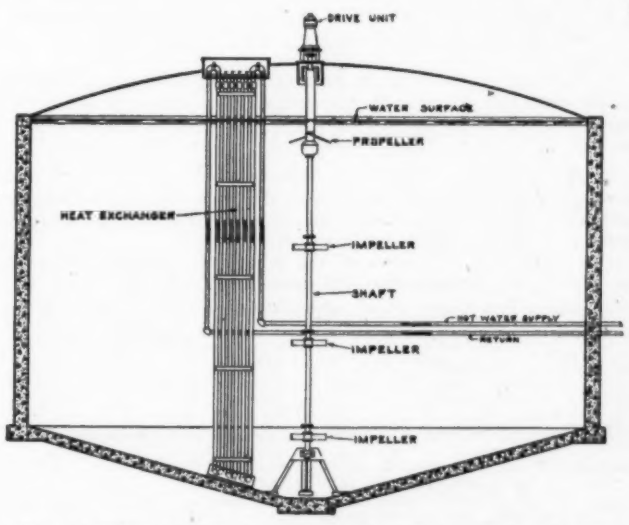

Fig. 4. Digestion Tank with Vertical Bank Type of Heat Exchanger

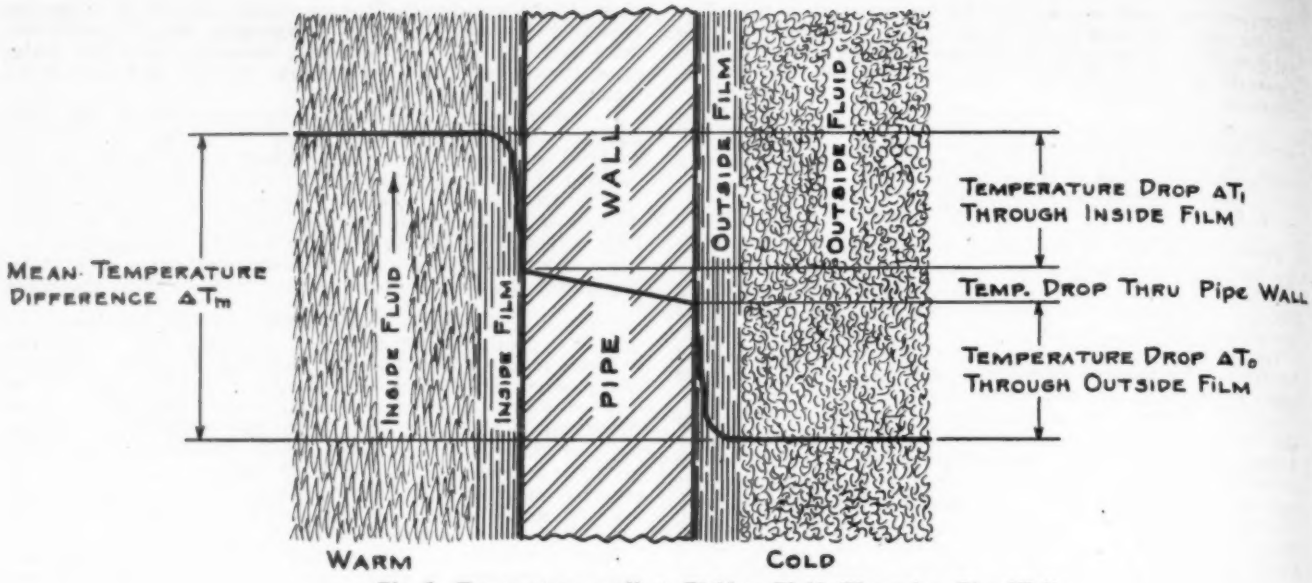

Fig. 5. Temperature gradient, Fluid to Fluid, Through a Pipe Wall

assumed that a state of equilibrium has been reached; i. e., the temperature gradient is assumed to remain constant and not change with time, and the rate of heat transfer through the wall of the pipe is assumed equal to the rate at which heat is absorbed by the liquid outside of the pipe. In addition, the effect of radiation is neglected, since the rate of heat transfer by radiation will be negligible compared to the rate of heat transfer by convection.

Film Coefficient.—From the above discussion it can be seen that there is no difference between this over-all film coefficient and the film coefficient f previously defined under "Notation used in heat loss formulae." It can be conveniently re-defined as the rate of heat transfer by convection between the inner or outer surface of a pipe wall and the main body of the adjacent fluid, in B.t.u./hr./sq. ft.°/F. temperature difference. Thus,

$$H_c = A\, f\, (\Delta T) \qquad (9)$$

where H_c = rate of heat transfer by convection, B.t.u./hr.
f = film coefficient, B.t.u./hr./sq. ft. °F.
A = area of wall surface in sq. ft.
ΔT = temperature difference between the surface of the wall and the main body of the fluid in °F.
ΔT_i = inside temperature difference.
ΔT_o = outside temperature difference.

Factors Affecting the Film Coefficient f.—There are several types of heat transfer by convection. In this study we are concerned only with the type in which the fluid does not change phase, i. e., the fluid remains either a liquid or a gas during the process. In this type of heat transfer, the film coefficient depends upon the turbulence of the fluid, increasing as the turbulence increases. The film coefficient also depends upon whether a fluid is being heated or cooled. The difference in the film coefficients for heating and cooling decreases as the turbulence of the fluid increases.

In addition to the various factors already mentioned, the film coefficients are affected by the presence of scale or other deposits on either surface of the pipe wall. Such deposits act as insulation, and may greatly reduce the rate of heat transfer.

Turbulent Flow Inside of a Pipe.—Where a fluid is flowing through a pipe, the film coefficient will increase as the velocity increases. At very low velocities, the flow will be streamline or laminar, and at higher velocities, it is usually turbulent. Also, for natural or free convection, the turbulence and film coefficient increase as the temperature difference ΔT increases.

The critical velocity above which fluid flow in a pipe is turbulent and below which it is streamline can be obtained from:

$$v = \frac{0.58\mu}{D\rho} \qquad (10)$$

Illustrative Problem 3 (*Critical velocity for turbulent flow*)

where v = velocity in ft./sec.
μ = viscosity in lb./ft./hr.
D = inside pipe diameter in feet.
ρ = density in lb./cu. ft.

Calculate the critical velocity for water in a 3-inch inside diameter pipe. The mean temperature of the water is 130° F. From Table 4, the viscosity of this water is 1.31 lb./ft./hr., and the density is 61.58 lb./cu. ft. Then, from Equation (10)

$$v = \frac{0.58 \times 1.31}{.25 \times 61.58},$$

$$= .049 \text{ ft. per sec. critical velocity.}$$

TABLE 4.
Density and Viscosity of Water

Temperature °F.	Density ρ lb./cu. ft.	Viscosity μ lb./ft./hr.
70	62.31	2.42
80	62.21	2.17
90	62.12	1.96
100	62.00	1.75
110	61.87	1.57
120	61.71	1.43
130	61.58	1.31
140	61.42	1.21
150	61.20	1.11
160	61.03	1.01
170	60.78	.92

Forced Convection Outside of a Pipe

Due to the increased velocity of movement of the liquid past a heat exchanger with forced convection produced by mechanical agitation or stirring, the resistance of the film to the transfer of heat is correspondingly decreased. In general, the decrease in resistance, or in other words, the increase in the film coefficient, is proportional to the velocity of motion past the heat exchanger. Where the agitation of the liquid is irregular, it is very difficult to estimate liquid velocities. But where a steady, uniform stirring action is present, the contents of a circular tank assume a definite motion which depends upon the type and speed of the stirring mechanism.

Positive stirring mechanisms usually found in sludge digestion tanks consist of short horizontal blades mounted on a vertical shaft, as illustrated in Figure 6. The speed of rotation is generally about 60 r.p.m.

The entire liquid mass in a circular tank will not rotate with the same rotary speed as that of the stirrer. The greater the distance from the axis of rotation, the slower will be the rotary motion. It has been determined that the liquid speed of rotation very closely varies as the square root of the diameter of the vertical plane of motion. Thus, the velocity of horizontal motion of the liquid at any distance z from the axis of the stirrer will be

$$v = \frac{\pi\sqrt{2z} \times \text{r.p.m. of stirrer}}{60} \qquad (11)$$

where v = Velocity in ft./sec.
z = Distance in feet from stirrer to vertical plane of liquid motion.

The action of this type of stirring is clearly shown by Figure 6.

Mean Temperature Difference ΔT_m.—The temperature difference between the hot water inside a heating pipe and the cooler water in the digestion tank does not remain constant throughout the length of the heat exchanger. The temperature difference between the two fluids is greatest at the point where the pipe first enters the tank liquid, and smallest where it leaves.

A more exact *mean temperature difference* is a logarithmic function of the two terminal temperature differences. However, for ordinary sludge digestion practice, the arithmetic mean of the terminal temperature difference can be used instead of the logarithmic mean without introducing an error in this value of more than 3 per cent.

Illustrative Problem 4 (*Mean Temperature Difference*)

The average temperature of the liquid in a sludge digestion tank is 85° F. The temperature of the hot water supply to the circular pipe coil is 135° F., and of the return 120° F. Determine the mean temperature difference.

$$\Delta T_m = \frac{(135 - 85) + (120 - 85)}{2}$$

$$= 42.5°\text{F.}$$

Determination of Film Coefficients

In the design of sludge digestion tank heat exchangers, we may be concerned with five different types of convection for which film coefficients must be determined, namely

Case 1. Water cooled inside of horizontal or vertical pipes, turbulent flow.

Case 2. Water heated outside of single horizontal pipes, forced convection.

Case 3. Water heated outside of single horizontal pipes, free convection.

Case 4. Water heated outside of vertical banks of piping, free convection.

Case 5. Water heated outside of vertical banks of piping, forced convection.

The same method is used in each case for the determination of the film coefficient. Charts have been prepared which show for each case an arbitrary or assumed coefficient f_b called the "base coefficient." Correction factors are then given for changing these values of f_b to conditions of temperature and pipe diameter other than those assumed for the charts. The general equation for the film coefficient is

$$f_i \text{ or } f_o = f_b \times F_t \times F_d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Where f_i = inside film coefficient, B.t.u./hr./sq. ft./°F.
f_o = outside film coefficient, B.t.u./hr./sq. ft./°F.
f_b = film coefficient, "base" conditions, B.t.u./hr./sq ft./°F.

Fig. 6. Vertical Stirring in a Sludge Digestion Tank
(*By courtesy of The Dorr Company*)

F_t = temperature correction factor corresponding to the mean temperature T_m of the main body of the water.
F_d = pipe diameter correction factor corresponding to the pipe diameter.

Case 1. *Water Cooled Inside of Horizontal or Vertical Pipes Turbulent Flow.*—The film coefficient f_i can be determined from the following equation:

$$f_i = f_b \times F_t \times F_d$$

Where f_b = base value of film coefficient, from Fig. 7.
F_t = temperature—correction factor, from Table 5.
F_d = diameter—correction factor for inside diameter of pipe, from Table 6.

TABLE 5.

Temperature Correction Factor for Water—Case 1

Aver. Temp.	F_t
50°F.	0.66
100°F.	1.00
150°F.	1.30
200°F.	1.56

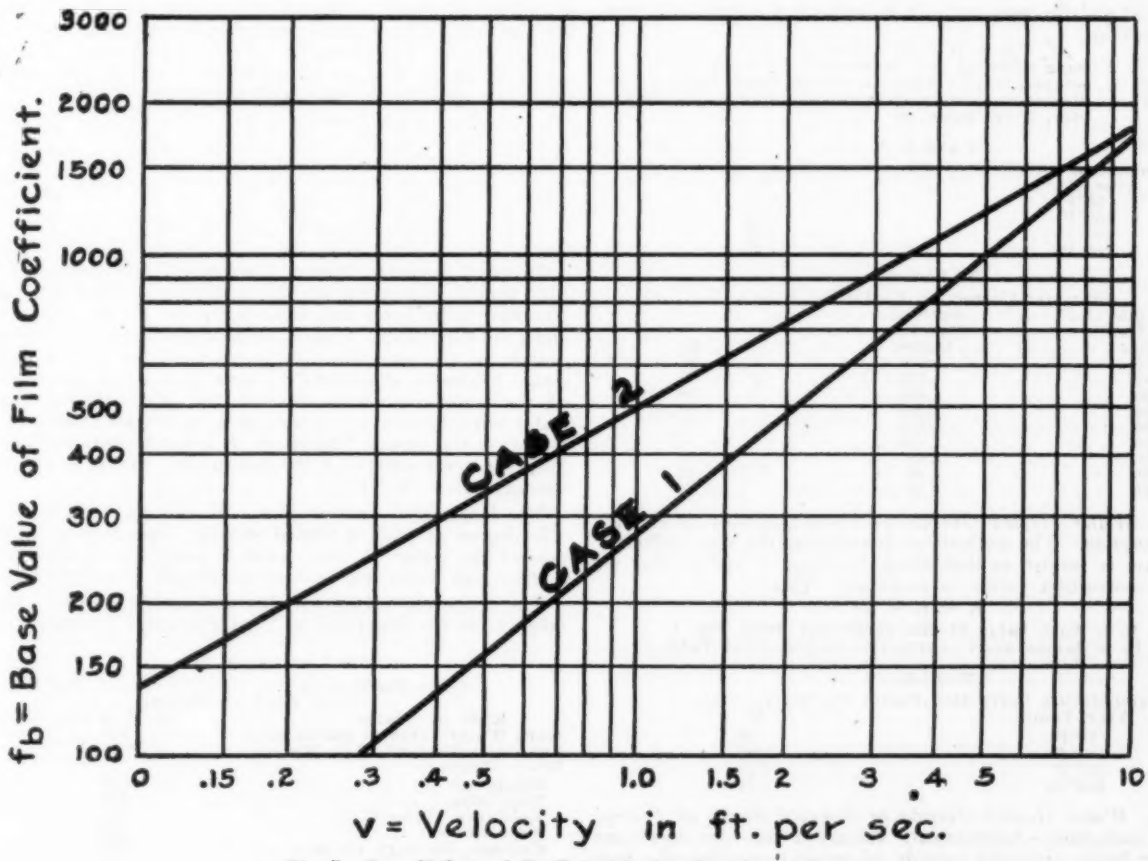

Fig. 7. Base Values of Coefficient f_b for Case 1 *and Case* 2

TABLE 6.
Diameter Correction Factor for Case 1

Inside Pipe Dia. Inches	F_d	Inside Pipe Dia. Inches	F_d
0.20	1.38	1.20	0.97
0.30	1.27	1.30	0.95
0.40	1.20	1.40	0.94
0.50	1.15	1.50	0.92
0.60	1.11	....	....
0.70	1.08	2.00	0.87
0.80	1.05	2.50	0.83
0.90	1.02	3.00	0.80
1.00	1.00	3.50	0.78
1.10	0.98	4.00	0.76

Case 2. Water Heated Outside of Single Horizontal Pipes, Forced Convection.—As previously stated, this type of convection differs from free convection by reason of the artificial movement of the liquid past the pipe caused by mechanical agitation such as stirrers. As in Case 1, the film coefficient f_o can be determined from

$$f_o = f_b \times F_t \times F_d$$

Where f_b = base value of film coefficient, from Fig. 7.
F_t = temperature—correction factor, from Table 7.
F_d = diameter—correction factor for inside diameter of pipe, from Table 6.

TABLE 7.
Temperature Correction Factor for Water—Case 2

Aver. Temp.	F_t
50°F.	0.77
100°F.	1.00
150°F.	1.16
200°F.	1.30

TABLE 8.
Diameter Correction Factor for Case 2

Nominal Pipe Dia. Inches	External Pipe Dia. Inches	F_d
.75	1.050	.98
1.00	1.315	.90
1.25	1.660	.81
1.50	1.900	.75
2.00	2.375	.68
2.50	2.875	.63
3.00	3.500	.58
3.50	4.000	.54
4.00	4.500	.50

Case 3. Water Heated Outside of Single Horizontal Pipes, Free Convection.—In this case the base value of the film coefficient is obtained from Fig. 8 as a function of ΔT_o in °F., in which ΔT_o is the temperature difference between the main body of fluid and the pipe wall. It is sufficiently accurate to take ΔT_o as $\frac{1}{2}\Delta T_m$.

$$f_o = f_b \times F_t \times F_d$$

Where f_b = base value of film coefficient, from Fig. 8.
F_t = temperature—correction factor, from Table 9.
F_d = diameter—correction factor for outside pipe diameter, from Table 10.

TABLE 9.
Temperature Correction Factor for Water—Case 3

Aver. Temp.	F_t
50°F.	0.77
100°F.	1.00
150°F.	1.15
200°F.	1.26

TABLE 10.
Diameter Correction Factor for Case 3

Nominal Pipe Dia. Inches	External Pipe Dia. Inches	F_d
.75	1.050	.98
1.00	1.315	.93
1.25	1.660	.88
1.50	1.900	.85
2.00	2.375	.81
2.50	2.875	.77
3.00	3.50	.73
3.50	4.00	.71
4.00	4.50	.69

Case 4. Water Heated Outside of Vertical Banks of Piping, Free Convection.—The method for determining the film coefficient in this case is simjlar to that given for Case 3, except that no diameter—correction factor is necessary. Thus

$$f_o = f_b \times F_t$$

Where f_b = base value of film coefficient, from Fig. 8.
F_t = temperature—correction factor, from Table 11.

TABLE 11.
Temperature Correction Factor for Water—Case 4

Aver. Temp.	F_t
50°F.	.73
100°F.	1.00
150°F.	1.19
200°F.	1.33

Case 5. Water Heated Outside of Vertical Banks of Piping, Forced Convection.—Approximate values of the film coefficient for water being circulated outside of vertical; parallel-tube heat exchangers by artificial stirring or agitation can be determined as a function of the film coefficients determined for single tubes in Case 2. Thus

$$f_o = 1.2 \times f_{s.t.}$$

in which $f_{s.t.}$ should be evaluated at a velocity as estimated at the narrowest section between the parallel pipes of the unit.

Over-all Heat Transfer.—In the type of heat transfer equipment commonly used in sludge digestion tanks, one fluid receives heat from another fluid, the two fluids being separated by the solid wall of a pipe or tube. When designing such heat exchangers, the temperatures of the fluids inside and outside the pipes are usually known, or are controlling criteria, but the temperature of the pipe wall is not known. Consequently, the expected rate of heat transfer cannot be calculated directly from the film coefficients, since these are based on the temperature difference between the *pipe wall,* and the fluids. However, the expected rate of heat transfer can be readily calculated from the *over-all coefficient U,* because this coefficient is based on the temperature difference between the two fluids. The coefficient U can be defined as the rate of heat transfer from one fluid to another per unit area of the separating wall per degree mean temperature difference between the two fluids. Thus

$$H = AU(\Delta T_m) \quad \text{..... (13)}$$

Where H = total heat transfer in B.t.u. per hour.
U = the over-all coefficient, B.t.u./hr./sq. ft./°F.
ΔT_m = the mean temperature difference between the main bodies of the fluids on each side of the separating on pipe wall in °F.

Relation Between Film Coefficients and Over-all Coefficient.—By the resistance concept, the over-all coefficient U can be calculated from the film coefficients and the conductivity coefficient of the pipe wall when these are known. For thin-walled pipes, the area is based upon the outside surface. Thus, for clean pipes,

$$\frac{1}{U} = \frac{1}{f_i} + \frac{b}{k} + \frac{1}{f_o} \quad \text{..... (14)}$$

Where f_i = film coefficient for the inside of the pipe, B.t.u./hr./sq. ft./°F.
f_o = film coefficient for the outside of the pipe, B.t.u./hr./sq. ft./°F.
f = thickness of pipe wall in inches.
k = coefficient of thermal conductivity of the pipe wall, B.t.u./hr./sq. ft./°F./inch of thickness.

Equation (14) is the theoretical formula for the resistance 1/U to the transfer of heat between the two main bodies of fluid. However, when the values of the coefficients f_i, f_o and k are examined, it can be readily seen that the resistance b/k offered by the pipe wall is most often negligible compared to the resistances $1/f_i$ and $1/f_o$. Therefore, for practical purposes, sufficiently accurate values of the over-all coefficient U can be calculated if the resistance through the pipe wall is omitted. Thus

$$\frac{1}{U} = \frac{1}{f_i} + \frac{1}{f_o} \quad \text{..... (15)}$$

and

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o}} \quad \text{..... (16)}$$

Effect of Scale on Over-all Coefficient U.—Equations (15) and (16) for calculating the over-all coefficient U involve the assumption that both inner and outer surfaces of the pipe are clean and free from scale. Under sludge digestion tank conditions, the outside of the pipe will always have a crust or scale of appreciable thickness, dependent to some extent on the temperature of the water circulated through the pipe. Higher circulating water temperatures are conducive to a greater degree of incrustation on the pipes. Therefore, it is good operating practice to keep the temperature of the hot water supply to the heat exchanger below 150° F.

The inside of a heating pipe will also accumulate some scale. The degree of scale is almost entirely dependent upon the hardness of the water. A hard water is conducive to scale formation while a soft water will be correspondingly free from this trouble.

The following values for dirt and scale coefficients have been taken from the Standards of Heat Exchange Institute[3].

TABLE 12.
Scale Coefficients "S" in B.t.u./hr./sq. ft./°F.
S = Scale Coefficient

Kind of Water	125°F. or less	Over 125° F.
Hard Water (over 15 grains/gal.)	330	200
Lake and Eastern Well Waters	1000	500
River Waters		
Maximum	500	330
Mississippi	330	250
Delaware, Schuylkill	330	250
East River	330	250
Chicago Sanitary Canal	130	100
Sewage Sludge	70	50
Distilled Water	2000	2000

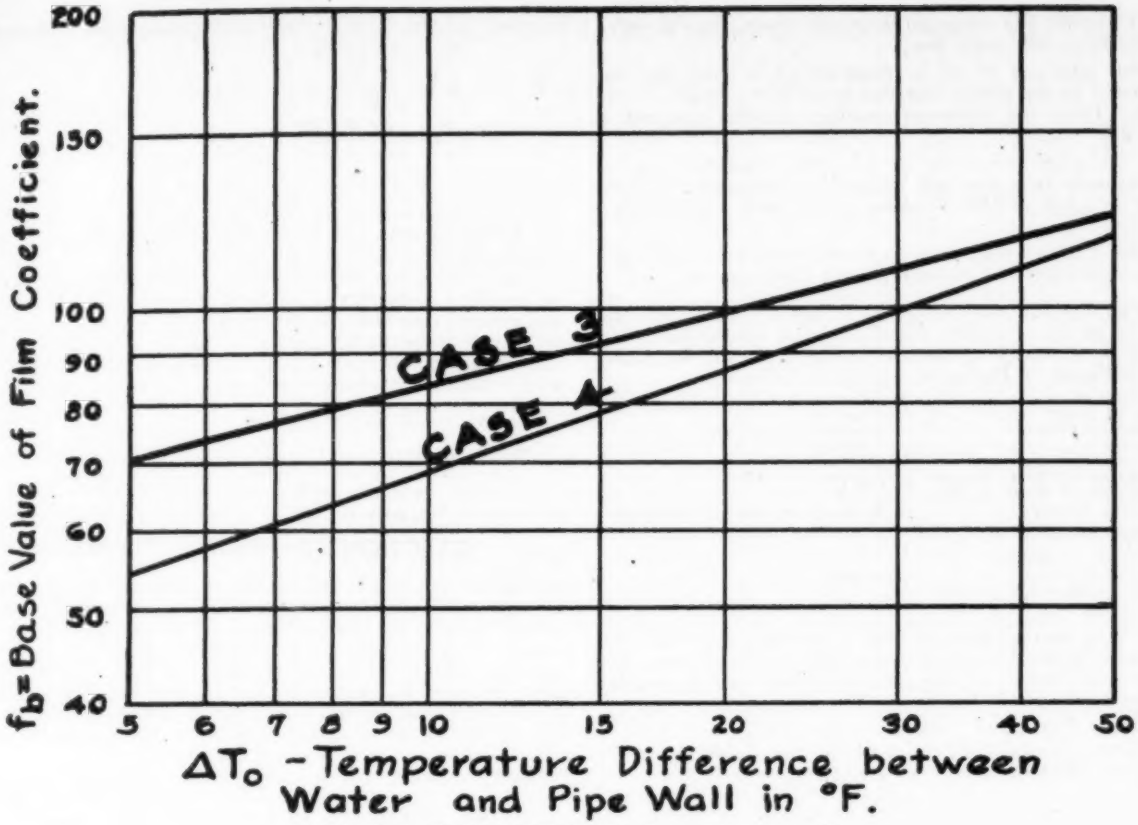

Fig. 8. Base Values of Coefficient f_b for Cases 3 and 4

Therefore, if the resistances due to inside and outside scale formations are added to Equations (15) and (16), then for thin-walled pipes

$$\frac{1}{U} = \frac{1}{f_i} + \frac{1}{f_o} + \frac{1}{S_i} + \frac{1}{S_o}$$

$$U = \frac{1}{\frac{1}{f_i} + \frac{1}{f_o} + \frac{1}{S_i} + \frac{1}{S_o}} \quad \text{..... (17)}$$

where S_i = inside scale coefficient, B.t.u./hr./sq. ft./°F.
S_o = outside scale coefficient, B.t.u./hr./sq. ft./°F.

Circulating Water.—The quantity of hot water to be circulated through a heat exchanger depends upon the total heat to be transmitted, and the temperature drop between the hot water supply and return. Obviously, the greater the temperature drop for a given B.t.u. exchange, the lower is the quantity of hot water required, and vice versa. A practical temperature drop is about 20° F., as for example, if the hot water supply is 130° F., the return will be 110° F. Therefore, the quantity of water required is

$$Q = \frac{\text{B.t.u./hr.}}{(T_s - T_r) \times 60 \times \frac{8.33}{\text{B.t.u./hr.}}}$$

$$= \frac{}{(T_s - T_r) \times 500} \quad \text{..... (18)}$$

where Q = rate of hot water circulation, g.p.m.
T_s = temperature of hot water supply, °F.
T_r = temperature of hot water return, °F.

Illustrative Problem 5 (*Design of Heat Exchanger—Horizontal Heating Pipes with Free Convection*)

The sludge digestion tank shown in Figure 2 is to be provided with heat by means of a spiral-form horizontal heat exchanger. This problem is a continuation of Problems 1 and 2, the three problems comprising a comprehensive solution of a sludge digestion heating application. Pertinent data are as follows:

Heat required ..... = 256,900 B.t.u./hr.
Tank Floor to bottom pipe = 6 feet
Vertical spacing of pipes.. = 12 inches
Mechanical Agitation ..... = None
Convection ..... = Free
Temperature of Sludge.... = 85°F.
Temperature H.W. Supply. = 130°F.
Temperature H.W. Return = 110°F.
Circulating Water ..... = Well water, 100 ppm hardness

From Equation (18)

$$Q = \frac{256{,}900}{(130 - 110) \times 500} = 26 \text{ g.p.m.}$$

Since the base coefficient f_b for the inside film depends upon the velocity of flow through the pipe, it is necessary to assume a pipe size which appears in advance to fit the conditions. If the heat exchanger based upon this pipe size is found to be unbalanced, a second calculation must be made for another pipe size. If a 2½ inch internal diameter, wrought iron pipe is assumed, then the velocity of the hot water through the pipe is 1.68 ft./sec. Since this is greater than .049 ft./sec., the flow is turbulent (see Equation 10).

The inside film coefficient f_i can be obtained from Case I, and the outside film coefficient f_o from Case 3. From Figure 7, $f_b = 410$ B.t.u./hr./sq. ft./°F.; from Table 5 by interpolation, F_t for 120° F. = 1.12; from Table 6, F_d for 2½ inch pipe = 0.83. Hence,

$$f_i = 410 \times 1.12 \times 0.83$$
$$= 382 \text{ B.t.u./hr./sq. ft./°F.}$$

The average temperature difference ΔT_o, inside to outside water, is $(120 - 85)/2 = 17.5°$ F. From Figure 8, $f_b = 95$ B.t.u./hr.; from Table 9 by interpolation, F_t for 85° F. = 0.86; from Table 10, F_d for 2½ in. pipe = 0.77. Hence

$$f_o = 95 \times 0.86 \times 0.77$$
$$= 63 \text{ B.t.u./hr./sq. ft./°F.}$$

The inside and outside scale coefficients can be obtained from Table 13.

S_i = 500 B.t.u./rr./sq. ft./°F.
S_o = 70 B.t.u./hr./sq. ft./°F.

Thus in Equation (17)

$$U = \frac{1}{\frac{1}{382} + \frac{1}{63} + \frac{1}{500} + \frac{1}{70}}$$
$$= 28.8 \text{ B.t.u./hr./sq. ft./°F.}$$

The total effective area of heating pipe surface required to transmit 256,900 B.t.u./hr. can be obtained from Equation (13).

$$H = AU(\Delta T_m)$$

and

$$A = \frac{H}{U(\Delta T_m)}$$

$$= \frac{256{,}900}{28.8 \times (120 - 85)}$$
$$= 255 \text{ sq. ft.}$$

The external area of 2½ inch wrought iron pipe is .753 sq. ft.

per foot of length. The minimum length of heating pipe required will be 255/.753 = 338 lineal feet.

One spiral pipe coil of 39 ft. diameter (1 ft. less than the inside diameter of the sludge digestion tank) has a length of 123 lineal feet. Thus, the minimum number of coils required is 338/123 = 2.8.

A heat exchanger consisting of 3 — 39-ft. diameter coils of 2½ inch wrought iron pipe will satisfy the requirements of the problem if 26 g.p.m. of 130° F. water is circulated continuously.

Illustrative Problem 6 (Design of Heat Exchanger—Vertical Bank Type of Unit with Forced Convection)

The sludge digestion tank shown in Figure 4 is to be provided with heat by means of a vertical-bank type of heating unit. The sludge will be stirred by a vertical stirrer with stirring blades as shown in Figure 6. Pertinent data are as follows:

Heat required	= 256,900 B.t.u./hr.
Spacing of pipes	= 6 inches
Mechanical agitation	= Rotary Stirrer, 60 r.p.m.
Convection	= Forced
Temperature of Sludge	= 85°F.
Temperature of H.W. Supply	= 130°F.
Temperature of H.W. Return	= 110°F.
Circulating Water	= Well water, 100 ppm hardness

From equation (18)

$$Q = \frac{256{,}900}{(130 - 110) \times 500} = 26 \text{ g.p.m.}$$

If a 2½ inch internal diameter pipe is assumed as in Problem 5, the velocity of the circulating water will be 1.68 ft./sec. The inside film coefficient f_i can be obtained from Case 1, and the outside film coefficient f_o from Case 5.

From Figure 7, $f_b = 410$ B.t.u./hr./sq. ft./° F.; from Table 5 by interpolation, F_t for 120° F. = 1.12; from Table 6, F_d for 2½ inch pipe = 0.83. Hence

$$f_i = 410 \times 1.12 \times 0.83 = 382 \text{ B.t.u./hr./sq. ft./°F.}$$

The distance from the stirrer shaft to the center of the vertical heat exchanger is 5 feet. Since the speed of the stirrer is 60 r.p.m., the peripheral velocity of the liquid through the heat exchanger will be from Equation (11)

$$V = \frac{\pi \sqrt{10} \times 60 \text{ r.p.m}}{60} = 10 \text{ ft./sec.}$$

From Figure 7 (Case 2), $f_b = 1800$ B.t.u./hr./sq. ft./°F.; from Table 7 by interpolation, F_t for 120° F. = 1.06; from Table 8, F_d for 2½ inch pipe = .63. Hence, from Case 5

$$f_o = 1.2 \times f_{s.t.} = 1.2 \times 1800 \times 1.06 \times 63 = 1450 \text{ B.t.u./hr./sq. ft./°F.}$$

The inside and outside scale coefficients can be obtained from Table 13.

S_i = 500 B.t.u./hr./sq. ft./°F.
S_o = 70 B.t.u./hr./sq. ft./°F.

Thus, in Equation (17)

$$U = \frac{1}{\frac{1}{382} + \frac{1}{1450} + \frac{1}{500} + \frac{1}{70}} = 56.0 \text{ Bt.u./hr./sq. ft./°F.}$$

The total effective area of heating pipe surface required to transmit 256,900 B.t.u./hr. can be obtained from Equation (13)

$$H = AU\ (\triangle T_m)$$

and

$$A = \frac{H}{U\ (\triangle T_m)} = \frac{256{,}900}{56.0 \times (120 - 85)} = 131 \text{ sq. ft.}$$

The external area of 2½ inch wrought iron pipe is 0.753 sq. ft. per foot of length. The minimum length of heating pipe required will be 131/.753 = 174 lineal feet.

Each vertical pipe in the bank-type heat exchanger has 25 feet of its length immersed in the liquid to be heated. The horizontal hot water supply and return pipes will have a minimum length of 20 feet from the heat exchanger to the tank wall. Thus, the total length of effective 2½ inch piping, if six vertical pipes are used in the heat exchanger, will be

Heat exchanger—25 × 6	= 150 lin. ft.
H. W. supply and return—20 × 2	= 40 lin. ft.
Total effective length	= 170 lin. ft.

This heat exchange piping will meet the requirements of the problem if 26 g.p.m. of 130° F. water is circulated continuously.

SELECTION OF HEATING EQUIPMENT

Standard equipment and control devices for heating hot water are too well known to warrant much discussion here. The usual sources of heat are conventional coal, oil, or gas-fired hot water boilers. A great majority of municipal sewage treatment plants use one or more of these. However, in many industrial plants, low-cost steam or electric current is available, and in such cases it is usually much more economical to use these sources of heat than it would be to recover the gases of sludge digestion for heating purposes, or to use any auxiliary fuel.

Where steam is used as a prime source of heat, the digestion tank circulating water can be heated automatically to any desired temperature by means of an instantaneous type of shell and tube hot water heater. With this type of heater the steam is introduced in the shell, and the hot water is circulated through the tubes. The quantity of steam admitted into the heater is controlled by a thermostatically-operated steam valve.

Where electric current is used as a prime source of heat, large capacity electric circulation heaters are used. These heaters have limited storage capacity, and depend entirely upon the heating element to be of a size sufficient to heat the water as it is circulated through the heater. A thermostatically-operated switch controls the amount of electric current applied in order to maintain the hot water within a predetermined temperature range.

Hot water circulating pumps are almost mandatory in order to insure a positive circulation of the proper quantity of hot water through the digestion tank heat exchanger at all times. Such circulating pumps may be manually controlled, but it is preferable to operate them automatically by means of a thermostatic switch of the Minneapolis-Honeywell or Mercoid Corporation type. The actuating temperature in this arrangement must be the temperature of the digestion tank liquid which is being heated.

REFERENCES

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2. Downes—"Gas Collection and Sludge Heating," Sewage Works Journal, Pg. 72 (January, 1932)
3. Standards of Heat Exchange Institute, published by Heat Exchange Institute, New York City, 1937.
4. * Rawn—"Sludge Digestion Temperature Control With Live Steam," Water Works and Sewerage (July, 1942).

*Added by the editors. An article published since author's preparation of this paper.

(Ed. Note.—Since the author wrote this paper, an article titled "Sludge Digestion Temperature Control With Live Steam," by A. M. Rawn, appeared in the July, 1942, issue of WATER WORKS AND SEWERAGE. Mr. Rawn's article, which describes the use of live steam for direct heating of raw sludge, or to raise digestion tank temperatures by direct application, may also be found in the Reference and Data Section of 1943 issue.)

OPERATING ENGINES ON SEWAGE SLUDGE GAS*

Some Comments on Their Care and Operation

By THOMAS BROWN and GEORGE PRESTON

METHODS of sewage treatment, in which sludge is digested, made possible the production and connection of power producing gas from digesting sludge. In the earlier period of digestion of sewage sludge, the gas generated in the process was considered of no value, and it was burned to waste to prevent obnoxious odors. Then economy demands directed engineers to utilize the sludge gas in heating the sludge in the digestion tanks so as to maintain the required uniform digestion temperature, thereby improving the process of sludge digestion and the quality of digested sludge. In the past few years sludge gas has been put to use also in the generation of power by passing it from the digestion tanks through gas engines—these gas engines driving electric generators or air blowers or raw sewage pumps. To effect further utilization of the heat contained in the sludge gas, the jacket cooling water of the gas engines is passed through heat evchangers which heat the water circulated through the heating coils of the digestion tanks and building spaces. Additional heat is being recovered from the sludge gas by passing the engine exhaust through waste gas boilers to add additional thermal units to the hot water in the heat exchanger.

The Power in Sewage Sludge Gas

Gas from digesting sewage sludge is an excellent fuel for gas engines. It has an average heat value of 600 British thermal units per cubic foot, and values up to 650 or more units are obtained. Its composition is given in general as 64 per cent methane, 30 per cent carbon dioxide, 5 per cent nitrogen, a trace of hydrogen sulphide, and 1 per cent other gases .The gas is produced in a fairly uniform volume at all times in the normal operation of a sewage treatment plant; and possible peak flows or excess quantities may be stored in gas holders.

Generally a municipal sewage treatment plant of proper design can produce one cubic foot of gas per person in 24 hours; but an average conservative figure is three-fifths of a cubic foot. Supposing a sewage treatment plant serves a city of 100,000 people, and the average value of the sludge gas generated is 600 British thermal units per cubic foot, and assuming that three-fifths of a cubic foot of gas is generated per person per day, then the brake horsepower developed is: $(100{,}000 \times 3/5 \times 600)$ $(24 \times 10{,}000)$ or 150 horsepower. If one cubic foot of gas is generated per person per day, the horsepower generated would be 250 for a population of 100,000. If garbage is ground into the sewage, the gas production might be doubled, giving a power production of 500 horsepower per 100,000 population, or 5 per 1,000.

Scrubbing Sludge Gas

If the sludge gas contains an excessive quantity of H_2S or hydrogen sulphide, the pistons and cylinder walls of the engine are likely to be harmed; for the products of combustion, namely, the water and sulphur dioxide (SO_2), unite to form the very corrosive sulphurous acid (H_2SO_3); but any amounts of volatile sulphide are just as objectionable in the engine fuel as is hydrogen sulphide.

If the content of sulphide in sludge gas should exceed 0.07 per cent by volume, or about 50 grains in 100 cubic feet of gas, a gas scrubber should be placed ahead of the gas engine. The sulphur in the state of hydrogen sulphide is removed in the scrubber by passing the sludge gas through a bed of finely divided iron oxide held in wood shavings. The iron oxide reacts with the hydrogen sulphide to form water and sulphide of iron in accordance with the equation $Fe_2O_3 + 3H_2S = Fe_2S_3 + 3H_2O$. The wood shavings serve only as a sponge for the iron, keeping open the mass of iron oxide, so the gas can pass through the scrubber with a minimum of resistance. In order to promote the chemical action between hydrogen sulphide and iron oxide, the temperature of the gas scrubber should be kept above 60 degrees Fahr. Artificial heat may have to be supplied.

The gas scrubber may be built readily by the operating staff of the sewage treatment plant. If 160,000 cubic feet of gas is to be scrubbed per day, containing about 100 grains of hydrogen sulphide in 100 cubic feet of gas, the scrubber should be figured on the following basis: Enough iron sponge should be provided to last about 60 days. There is about 20 pounds of ferric iron in one cubic foot of sponge. Theoretically, 20 pounds or one cubic foot of ferric iron sponge will react with 127,000 grains of hydrogen sulphide. In actual operation, this reaction capacity will be cut to about one-third, or to 40,000 grains of hydrogen sulphide. Figuring 100 grains of hydrogen sulphide in 100 cubic feet of gas, and 160,000 cubic feet of gas per day, the total hydrogen sulphide to be removed in 60 days is 9,600,000 grains. Therefore the amount of iron sponge required is 240 cubic feet. The gas scrubber tanks should be large enough to hold this amount of iron sponge, and in addition there should be at least three inches of space at the bottom of the scrubber, underneath a tray, this space aiding in better distribution of the incoming gas to the sponge bed. The scrubber should be coated inside with a bituminous paint.

The iron sponge can be used over again after regeneration. When it has become exhausted or sulphided in the 60-day period, it is exposed carefully to the air so as to allow the iron sulphide to absorb oxygen, enabling the iron to revert back to its original ferric oxide state according to the equation $2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$. There is so much heat generated in this reaction that there is danger of the iron sponge starting to burn and be destroyed. The rate of heat generation can be controlled by wetting the exhausted iron sponge thoroughly with water, taking it then from the scrubber tank and piling it in the open air. After the sponge has charged from blacw to brown in color, it can be placed back in the scrubber; it should be placed uniformly and tamped lightly as it is placed to fill all space evenly. The iron sponge can be regenerated two or three times in this manner, before it has to be discarded finally.

Engines for Sludge Gas

Gas engines for running on sludge gas are built generally in sizes from 15 to 1,800 horsepower. They are connected direct to electric generators, or to air blowers, or to sewage pumps by way of gearing, or to other mechanical equipment. They are used full or part time, all or part of the installation, as gas becomes available. For running a gas engine full load and full time in spite of insufficient sludge gas supply, city gas can be made available for standby.

The heavy duty slow speed gas engine is preferred to other gas engines. It can run for several years continuously with low cost of maintenance and repairs. In the smaller size of gas engine the valve-in-head type is preferred. By installing a carburetor, gasoline may be used as fuel instead of gas. The gas engine can be expected to have a normal life of 20 years. Repairs will run about $2.00 per year per brake horsepower. The gas engine is required to run almost continually, for if it is shut down, generally considerable electric power must be purchased and a high kilovolt-ampere demand results.

The sludge gas enters the engine by way of a gas mixing valve in which the gas is mixed with atmospheric air in proper proportion. The valve has a function which is similar to that of the carburetor used in gasoline engines, and it contains an air valve and a gas valve, each regulated separately; due to this arrangement the fuel mixture can be changed to suit the changing British thermal unit content of the gas. Just ahead of the gas mixing valve, the gas pressure is reduced to atmospheric pressure by use of a suitable pressure regulator. By installing a gas reservoir between the pressure regulator and the mixing valve, the operator can maintain a constant supply of gas at the atmospheric pressure; and this reservoir should be at least 30 cubic inches in size per horsepower of engine rating.

Generally speaking, at full load the fuel consumption of the gas engine does not exceed 10,000 British thermal units per brake horsepower-hour, which equals 15,000 British thermal units per kilowatt hour. If the sludge gas has a low heat value of 575 British thermal units per cubic foot, a kilowatt-hour generated requires 26.1 cubic feet of gas at full load, 27.5 at 5/6th load, 29.3 at ⅔rd load, and 32.7 at ½ load.

Installations of Gas Engines

Hundreds of installations of gas engines running on sewage sludge gas have been made during the last few years, including

*This article, from *The International Engineer* of May, 1941, so well tells the story of power generation from sludge digestion gas, that we have asked permission to reproduce it.—Ed.

at least 3,500 horsepower at Tallmans Island plant, New York City; 1,820 at the Coney Island plant, New York City; 835 at Peoria, Ill.; 360 at Detroit, Mich.; 300 at Cedar Rapids, Iowa. [See appended list of engine installations. The largest will be that at New York's Jamaica plant, with 3 engines of 1,440 H.P. each—i. e., 4,320 total H.P.—Ed.]

Gas and Air System.—The fuel gas system of the engine consists as a rule of a gas holder or reservoir (which may be a floating cover on the digester tank), a gas meter, a pressure regulator, a mixing valve, and a governor. The governor needs careful attention; its rotating parts must be kept lubricated properly—when the lubricating oil is discharged back to the crank case, attention must be given that the blowby gases are not depositing water in the governor. Keep all flat wearing surfaces of the governor free of depressions so that it continues to respond smoothly and rapidly. Inspect the governor every time the piston is removed.

Draw all intake air through adequate filters; for dust drawn into the engine with the air accelerates the wear of moving parts. All intake air lines should be large which prevents high losses in pressure when the engine is running at full load. The mixiing valves need adjustment and lubrication occasionally. Water should be kept out of the gas piping.

Air Starting and Safety Devices

The air starting system of the gas engine includes air compressor, air reservoir tanks, and air piping. The air compressor should be inspected occasionally and repaired if necessary. See that the condensate drains properly from the air starting tanks and piping. Check blow-off cocks, and float-operated condensate separators on the tanks, periodically to be sure they remove water from the air storage tanks and air lines, and prevent the fouling of spark plugs due to injection of water into the engine cylinder.

The ignition system consists of magnetos, or battery-operated spark coils, timed distributors, high tension distribution wiring and spark plugs. Keep the voltage generated at a minimum to keep the magneto or spark coil in best operating condition; do this by keeping the spark gaps at or near the minimum for production of a good spark. Change or clean spark plugs and re-adjust the gap when the gap increases from the normal 0.025-inch setting to about 0.050 inch. The double electrode plugs are well suited to the gas engine. Spark plug gap adjustment may be required once a month. Clean magneto and distributors once each year and adjust or replace electrodes as needed. Check timing settings against the flywheel markings every time the timing mechanism is dismantled. Inspect high tension wiring for cracks and take precautions against possible cross firing where wires are adjacent to each other.

The engine protective devices generally are instruments actuated by pressure, temperature or mechanical movements, thereby operating electrical switches or relays. These relays and switches ground the magnetos and close the fuel gas valve, so that the engine is shut down. If the gas engine drives an electric generator, there is also a generator breaker which is tripped and the electrical system cleared for normal operation.

Pressure gauges, tachometers, pyrometers and other indicating devices should be kept in good operating condition. All delicate indicating devices and safety devices, and all gauges should be kept mounted on panels which are isolated from the engine so they will not wear due to vibration. The safety devices and gauges should be inspected and checked quite often to make sure they operate properly. Check the protective devices which shut the engine down when the temperature becomes excessive or when the pressure of cooling water or lubricating oil should drop below normal. Also check the overspeed protection device.

Maintenance Schedule

Following a routine maintenance schedule will insure the operation of the gas engine with a minimum of shutdowns. Details of maintenance on the gas engine are affected by the size, speed, operating condition and design of the unit. The operating engineer should have a routine maintenance schedule for each engine to follow throughout the year. He should keep a complete record of all maintenance work on the unit. Such records will help to work out a more reliable maintenance schedule and overhauling schedule as the years pass; and it enables the engineer to keep a closer check on the performance of each engine part. Dated records should be kept on crankshaft allignment, clearance of piston rings, bearing clearance. The operating engineer should take note also of the condition of piston rings, pistons, liners, oil conditions, dimensions and replacements of piston rings, diameters of liners, etc.

Main Crankshaft and Connecting Rod Bearings

After the gas engine has been run for some time, the main crankshaft and connecting rod bearings should be inspected at the rate of once per year. The bearings should be checked for clearance. The main crankshaft bearings must be checked for proper alignment; this should be done after the main bearings are adjusted and whenever the pistons are removed. Any misalignment can be determined by measuring the deflection of the crankshaft flanges when rotating the shaft. Mount a sensitive deflection gauge between the parallel crank faces of the crankshaft and take readings at 90-degree intervals in the shaft rotation.

If the gas engine is run with misaligned main bearings, a repeated flexing of the crankshaft metal occurs and in the end there will be crystallization and failure of the shaft. If the measured deflection of a large gas engine is .003 inches, the bearings should be adjusted. The bearing adjustment can be done by removing and scraping the lower half of the main bearings until the proper alignment has been obtained. To estimate the clearance in bearings, the most satisfactory way is to remove the small shims, reassemble the bearing until it just binds in the shaft, and then reinsert the proper size of shim to provide the correct clearance.

Every two or three years the clearance between the wrist pin and wrist pin bushings should be measured. If there is a thump of pronounced intensity, it indicates that a wrist pin assembly has become defective. In this case press the pin out of the piston, and measure the diameter of both the pin and bushing with a micrometer gauge. If excessive wear has occurred, grind the pins to true circular section and install new bushings of correct diameter.

Cylinders and Pistons

About every six to eight months the piston should be removed from the gas engine so that carbon deposits can be removed from around the rings and so that any rings showing excessive wear can be replaced. Clean the piston and piston rings thoroughly of gumming oil and hard carbon. The oil holes back of the piston grooves should be cleaned. Replace the piston rings on the same piston from which they were removed. Stagger the ring gaps on opposite sides of the piston. Liner packing rings should be checked for tightness after the engine has been reassembled, by placing the water jacket under water pressure and watching for water leaks into the crankcase.

If pistons are operated for a prolonged time with piston rings stuck, the piston and liner may become scuffed or gouged. If there is an indication that the piston rings are not working properly, clean the piston and free the piston rings at the earliest hour possible. When excessive blowby of cylinder gases into the crankcase is noticed, or when there is a marked increase in the consumption of lubricating oil, it is likely that some of the piston rings have become stuck in the piston ring grooves. By removing the piston rings promptly and correcting the condition, excessive wear on pistons, piston rings and cylinder liners resulting from higher temperatures and poor lubrication is stopped or prevented.

When the piston is being cleaned, inspect the piston rings for wear and ring gap. After the piston rings have been placed on the piston, check the clearance between the rings and groove, by use of a feeler gauge. The seat for the piston ring should be square, and there should be no excessive taper in the ring groove, for this may lead to sticking of the rings. If power or compression rings are to be used over again, chamfer them slightly with a file to remove sharp wearing edges. The oil control rings of the scraper ring type should have a relatively small bearing area and also a sharp scraping edge.

It is best, after the head has been taken off and the liner and piston removed, to measure the diameter of the liner in both transverse and lateral direction at three points of the piston stroke. Then make a record of the readings and compute the amount and rate of wear. After a new engine has been run for some time, the average maximum increase in diameter of the liner may amount to from .0004 to .0005 inches in 1,000 hours of operation. Cylinder liners may stand three reborings, after which new ones should be installed. Any rings showing excessive ring gap, lack of tension and an undue reduction in radial thickness should *not* be used again.

Valves Need Checking

Whenever the engine is dismantled, check the air starting valves and the valve motion devices including gears, camshaft, cams, push rods, and valve operating rockers.

Reseat the exhaust and intake valves periodically to be sure

they will work properly. The exhaust valves should be reseated every two to three months, and the intake valves should be reseated every four to six months. If the valve discs and seats have become pitted, they should be placed in a lathe and ground with a carborundum wheel until all pitting is removed; or the pitting may be removed with a cutting wheel.

Small quantities of carbon and dust depositing between valve stems and guides may cause the valve to stick. This occurs most likely after the engine has been shut down. Clean the valve surfaces and inspect them for proper clearance. Excessive clearance of the valve stem will cause the valve to move sideways too much so that it may not close completely over the entire seat; and the valve disc may start to warp in reference to the stem. It is possible that the valve disc has warped already on the stem, and therefore will have to be aligned. If the valve guides have worn too much, cast iron bushings can be inserted to provide again a proper clearance. Hard steel bushing inserts may be obtained for the valve cages, and also replaceable valve seats.

In larger engines the valves should be in removable cages, or they should be installed in some other way which makes them easily removable for inspection and for grinding of valves. The operating staff should keep a stock of removable valve seat inserts.

If the valve does not seat properly, injury may result to the valve and the gas engine will lose power and operate unevenly. After the valves have again been assembled in their cages, the seating surface should be lapped in with a good grinding paste. Later the fit should be checked by using a colored paste, as for example prussian blue. First apply some prussian blue paste to the cage seat. Then wipe to a thin film with a dry cloth. Then place the valve in the cage. Then rotate the valve disc slightly. Then check the disc which should show a continuous ring of blue. If it does not, more grinding is necessary to make a true contact. Smaller valves may be ground completely more economically by the lapping method only.

Having replaced reground valves, the clearance between the valve stem cap and the valve operating mechanism should be adjusted properly. Inspect this clearance quite often for about two days after they have been put in service and adjust whenever necessary; for there may be a change in clearance for a day or two due to the hammering of the valve. It is a good plan to *inspect the valves about once a week* to make sure that a proper clearance is maintained.

Lubrication

Most careful attention should be given to the lubricating oil system consisting of engine sump or oil storage tank, oil pump, oil filter, or screen, oil cooler, oil centrifuge, or purifier, and oil distribution lines. The best quality of oil obtainable for the purpose should be used in the plant. After a new installation has been started, the oil should be checked say weekly for suspended solids, for viscosity, for water, for neutralization number, and also for sulphur content if the gas burned contains an appreciable amount of hydrogen sulphide. An oil changing and oil purification schedule should be worked out from experience to meet engine requirements; and once this has been done, the *oil conditions* may have to be *inspected only about once a month.*

When operating conditions are normal and a batch system of purifying the oil is used, the oil should be removed fully once a month and new or purified oil substituted. The oil tends to build up solids, due to thermal decomposition. Water which forms in the crankcase of the engine from blowby of combustion gases, leads to the forming of oil-water emulsions which are sometimes called sludge. When accumulating in the crankcase, this sludge should be removed completely before any new or purified oil is added to the system. The rate of oil decomposition and the formation of sludge being increased by excessive blowby of the combustion gases, oil inspection and oil changing may be required more frequently if excessive blowby occurs.

The operator should never allow the sludge to accumulate so it will be pumped through the oil circulating system. The oil pump for the main distribution system should be checked frequently to insure the correct discharge pressure. Oil screens installed to remove coarse particles should be cleaned every three or four months.

It is best to remove the water and sludge from the crankcase by using a gear pump with flexible suction hose. Do not wipe the crankcase with rags, for the lint left might be pumped through the oil lines and deposited on the screen, which will result in lower oil pressure in the system.

Oil Cooling and Purifying

The temperature of the oil in the cooler should not exceed 160 degrees Fahr., and water should not be allowed to leak into the oil. There should be thermometers in the oil line before and after the coolers. When the temperature differential for operating the cooler is not sufficient, the cooler should be bypassed and cleaned. The cooler should be cleaned periodically; remove the tube bundle and boil it in a 10 per cent solution of tri-sodium phosphate (which is an emulsifying agent) until the sludge settled in the tube bundle is removed and softened. Then blow the bundle out with compressed air to remove traces of softened material.

The oil in the circulating system should not contain more than 0.75 per cent suspended solids. The solids content can be reduced in a centrifuge to about 0.15 per cent, and the water content to less than 0.1 per cent moisture. For centrifuging, the oil should be heated first to 140 to 160 degrees Fahr., with a relatively low-temperature element. The oil heater should not be of the instantaneous type, for the element in this heater is so hot that there is danger of breaking down the oil, causing carbon deposits around the heater, which insulates the heater and causes it eventually to burn out.

When the engine is dismantled, check the oil distribution lines. Check also the link mechanism of the force feed lubricator for wear and replace worn parts if any. Also check the lubricating pump for rate of discharge.

Waste Heat Equipment

The cooling water should be maintained soft enough to prevent calcium and magnesium salts from depositing on the surface of the water jackets. The engine cooling water jackets should be inspected periodically for scale deposits. If there are heavy deposits, correct the water conditions to prevent further deposits. Excessive deposits overheat engine parts as a result of lowering the heat transfer rate. It is preferable to use a closed system of water cooling; for in the open system using evaporation by cooling tower, deposits are built up. When a closed cooling system is used, the return water to the engines can be kept between 90 and 100 degrees Fahr. and the water discharged from the engine jackets should not exceed 160 degrees Fahr. Periodically check the water pumps, water jackets and cooling facilities of the cooling water system.

All or part of the waste heat from the engine jacket cooling water can be recovered for use in the water heating system of the building spaces and digestion tanks. This heat recovery saves coal or oil fuel which would otherwise be required to supply the heating system. In a four-cycle slow-speed gas engine of about 90-horsepower capacity, for example, operating under full load, the heat content of gas fuel is applied as follows: 25.5 per cent in useful work, 3.5 per cent in radiation, 33.5 per cent in jacket cooling water, 37.5 per cent in exhaust and friction. Practically all of the 33.5 per cent of heat going to the jacket cooling water can be recovered in a hot water heating system.

It is recommended to *have the cooling water enter the engine jacket at between 110 and 130 degrees Fahr. and have it leave the engine at between 140 and 160 degrees Fahr.* To effect efficient cooling of the engine, about 3,300 British thermal units must be removed from the engine jacket water per brake horsepower per hour. In passing the engine jacket water through the heating coils of the digester, therefore, this amount of heat must be extracted from them both winter and summer; if not all of this amount of heat can be extracted from the so-called water cooler in the digester, (that is, the digester heating system), part of the jacket water has to be circulated through a separate water cooler, as for example during the summer season, to obtain the required cooling effect.

The heat that can be removed from the jacket water of a 90-horsepower engine under full load is 297,000 British thermal units per hour. For a 30-degree Fahr. temperature rise the amount of jacket cooling water required is 1,190 gallons per hour. Cooling of the water is effected in the digester heating system or in some other way, and a circulating pump of at least 1,190-gallons-per-hour capacity is needed to effect positive circulation of water. There should be a vented surge tank at the high point of the jacket water system, placed just ahead of the circulating pump or between the engine outlet and the cooler. There should be a thermometer at the cold water inlet and at the hot water outlet.

Waste Heat Boiler

In some gas engine installations the exhaust gases are exhausted to the atmosphere by way of exhaust silencers and waste heat boilers. If a waste heat boiler is used to extract enough heat from the exhaust gases to cool them from 900 degrees Fahr., to 300 degrees Fahr., and a high boiler water temperature is desired to guard against possible condensation and corrosion, the jacket cooling water of the engine may be pumped into the

boiler after preheated to 140 degrees Fahr. The waste heat boiler acts as a silencer for the engine, and if there is a by-pass around the waste gas boiler, it should have an exhaust silencer.

The waste heat boiler requires great care in operation. Water must not be permitted to condense on the gas side of the tubes if maintenance costs are to be kept low. Condensate forming on the gas side of the boiler tubes results in rapid corrosion and tube failure. When waste heat or exhaust gas boilers are not in use, they should be disconnected completely, for valves used in exhaust gas lines do not seat tightly and the gases filtering into the boiler corrode the gas side of the tubes due to deposit of condensate.

Condensation of water on the gas side of tubes, due to cold boilers, can be prevented by generating steam in the boiler and converting it to heating uses; or by heating water in the boiler and controlling its flow in such a manner that the temperature of the water will not drop below 180 degrees Fahr. At points where radiated heat will affect the operation of engine devices, the exhaust gas lines should be kept insulated. The heat radiated from the engine, which is about 3.5 per cent, cannot be transferred to the hot water heating system; this radiation helps cut down the heating load by heating the engine room partially.

The dewpoint, or the temperature at which condensation on the cooling surfaces of the waste heat boiler begins, is about 130 degrees Fahr. As the gas contacts the boiler surface, there is a sudden drop in temperature; therefore the exhaust gases can be cooled only to that temperature where they will leave the boiler without condensation. *The inlet temperature of the boiler water should not be less than 130 degrees Fahr.; and a safe minimum temperature of the exhaust gas is 300 degrees Fahr.*

If feed water is not available at 130 degrees Fahr., the waste heat boiler may be used to generate low-pressure steam which is passed to an independent tubular heater, the condensate returning to the waste heat boiler generally well above 130 degrees Fahr. Excess sludge gas, that is not used in the gas engine, can be fired in a gas boiler to supplement the waste heat recovery boiler.

Exhaust gases from a 4-cycle gas engine having water-cooled exhaust manifold, have a temperature of 800 to 900 degrees Fahr.; and exhaust gases from a two-cycle gas engine have a temperature of 300 to 500 degrees Fahr. A 90-horsepower four-cycle engine will produce about 1,130 pounds of exhaust gas per hour at full load, from which at least 150,000 British thermal units can be recovered per hour.

SLUDGE GAS ENGINE INSTALLATIONS IN THE UNITED STATES

Year	Location	No. of Units	Hp. Per Unit	Driving
1926	Plainfield, New Jersey	2	15	Blower
1928	Charlotte, North Carolina	1	225	Blower
	Charlotte, North Carolina	1	75	Pump
1930	Rockville Centre, New York	1	30	Blower
	San Bernardino, California	1	40	Generator
1932	Rockville Centre, New York	1	60	Blower
	Springfield, Illinois	1	180	Blower
1933	Fort Atkinson, Wisconsin	1	40	Generator
1934	Springfield, Illinois	1	157	Bl.&Gen.
	Menominee Falls, Wisconsin	1	5	Generator
1935	Ann Arbor, Michigan	1	120	Blower
	Burlington, Wisconsin	1	15	Generator
	Cedar Rapids, Iowa	1	210	Generator
	Durham, North Carolina	2	150	Generator
	Greencastle, Indiana	1	50	Blower
	Los Angeles County, California	1	200	Pump
	Madison, Wisconsin	1	230	Blower
	Monroe, Michigan	1	25	Pump
	Ontario, California	1	40	Blower
	Palo Alto, California	1	40	Generator
	Peoria, Illinois	1	535	Blower
	Peoria, Illinois	1	300	Blower
	Toledo, Ohio	1	300	Pump
	Toledo, Ohio	1	225	Generator
1936–37	Atlanta, Georgia			
	Intrenchment Creek	2	120	Generator
	Clayton	2	180	Generator
	Aurora, Illinois	2	75	Pump
	Battle Creek, Michigan	1	50	Pump
	Cheboygan, Michigan	2	120	Pump
	Davenport, Iowa	1	75	Pump
	Davenport, Iowa	1	75	Generator
	District of Columbia	1	1200	Generator
	Dixon, Illinois	1	30	Generator
	Edwardsville, Illinois	1	15	Generator
	Elmhurst, Illinois	1	30	Generator
	Grand Rapids, Michigan	1	50	Generator
	Green Bay, Wisconsin	1	120	Generator
	Green Bay, Wisconsin	1	90	Generator
	Hutchinson, Kansas	1	90	Generator
	Janesville, Wisconsin	1	30	Generator
	Kewanee, Illinois	1	30	Generator
	Kokomo, Indiana	1	45	Generator
	La Crosse, Wisconsin	2	90	Generator
	La Porte, Indiana	1	27	Generator
	Litchfield, Illinois	1	30	Generator
	Madison, Wisconsin	1	230	Generator
	Michigan City, Indiana	1	75	Blower
	Monroe, Wisconsin	1	30	Generator
	New York, New York—			
	Coney Island	3	300	Generator
	Oshkosh, Wisconsin	2	160	Generator
	Richmond, Indiana	1	120	Blower
	State College, Pennsylvania	1	15	Generator
	Topeka, Kansas	2	180	Blower
	Wichita, Kansas	1	75	Pump
1938	Albuquerque, New Mexico	1	150	Generator
	Cedar Rapids, Iowa	1	100	Pump
	Chicago Heights, Illinois	1	100	Blower
	Crawfordsville, Indiana	1	44	Blower
	Columbus, Ohio	3	750	Generator
	Detroit, Michigan	1	364	Generator
	Findlay, Ohio	1	90	Blower
	Fort Dodge, Iowa	1	275	Generator
	Greensboro, South Carolina	2	160	Generator
	Lake Charles, Louisiana	1	50	Blower
	Lansing, Michigan	1	240	Blower
	Michigan City, Indiana	1	74	Generator
	Newcastle, Indiana	1	45	Blower
	Okoboji, Iowa	2	40	Blower
	Pueblo, Colorado	3	75	Pump
	Wooster, Ohio	1	15	Pump
1939	Carlsbad, New Mexico	2	50	Pump
	Crawfordsville, Wisconsin	1	44	Pump
	Escanaba, Michigan	1	40	Generator
	Ithaca, New York	1	50	Pump
	Kenosha, Wisconsin	2	75	Pump
	Manitowoc, Wisconsin	1	75	Pump
	Manitowoc, Wisconsin	1	35	Pump
	Medford, Wisconsin	1	15	Generator
	Menominee, Michigan	1	19	Pump
	Midland, Michigan	1	15	Pump
	New York, New York—			
	Tallmans Island	2	800	Blower
	Tallmans Island	2	450	Blower
	Tallmans Island	2	350	Pump
	Tallmans Island	2	150	Pump
	Rock Island, Illinois	5	125	Pump
	Rock Island, Illinois	1	75	Generator
	Rock Island, Illinois	2	75	Pump
	Two Rivers, Wisconsin	1	43	Blower
	Two Rivers, Wisconsin	1	40	Pump
	Wausau, Wisconsin	1	75	Generator
	Wausau, Wisconsin	1	50	Generator
	Wausau, Wisconsin	1	50	Pump
1940	Adrian, Michigan	1	45	Blower
	Aurora, Illinois	2	50	Generator
	Belleville, Illinois	1	100	Blower
	Butler, Pennsylvania	1	80	Generator
	Cedar Rapids, Iowa	1	100	Pump
	Cleveland, Ohio	2	390	Blower
	Fort Wayne, Indiana	1	450	Blower
	Galesburg, Illinois	1	40	Pump
	Gary, Indiana	3	175	Pump
	Gary, Indiana	2	300	Blower
	Greenville, South Carolina	2	225	Generator
	Marion, Indiana	2	75	Blower
	Marion, Indiana	1	50	Pump
	Metairie, Louisiana	1	50	Blower
	New York, New York—			
	Jamaica	3	1450	Generator
	Coney Island	3	920	Generator
	Peru, Indiana	1	45	Blower
	Pontiac, Michigan	1	150	Blower
	Quincy, Illinois	2	44	Pump
	Shawano, Wisconsin	1	35	Generator
	Sharon, Pennsylvania	2	80	Generator
	South St. Paul, Minnesota	1	125	Pump
	Springfield, Missouri	2	198	Generator
	Stevens Point, Wisconsin	1	75	Generator
	Wisconsin Rapids, Wisconsin	1	75	Generator
1941	Carbondale, Illinois	1	28	Blower
	New Iberia, Louisiana	1	36	Blower
	New York, New York—			
	Bowery Bay	2	800	Generator
	Rahway, New Jersey	2	50	Pump
	San Angelo, Texas	1	20	Pump
	San Dimos, California	1	250	Pump
	Washington, D. C.	1	1200	Generator
1942	Columbus, Ohio	3	775	Generator
	El Paso, Texas	2	210	Generator
	Leesville, Louisiana	1	40	Blower
	Los Angeles County, California	2	110	Pump
	San Leandro, California	1	110	?
	Toledo, Ohio	1	310	Pump
	Toledo, Ohio	1	180	Generator
1943	Battle Creek, Michigan	1	50	Pump
	Fort Huacho, Arizona	3	1000	?
	Fort Huacho, Arizona	1	750	?
	Muncie, Indiana	1	50	Pump
1944–45	New York, New York—			
	26th Ward—Under contract.	3	1300	Generator
	Owls Head—Under design	6	1250	Generator
	Newtown Creek—Under design	5	1450	Generator
	Hunt's Point—Under design.	2	920	Blower
	Hunt's Point—Under design.	2	920	Bl. or Gn.

GAS ENGINE PERFORMANCE

Accomplishments at Marion, Ind.

By DAVID BACKMEYER
Supt., Sewage Treatment Works, Marion, Ind.

THE sewage treatment and garbage disposal plant at Marion, Ind., was put in operation in July of 1940. The plant is of the activated sludge type with separate sludge digestion. Two digestion tanks, each 65 ft. in diameter and equipped with Pacific Flush Tank Co. floating covers, provide a total digestion capacity of 167,000 cu. ft. With the exception of one district in the southern part of the city, which is served by a pumping station, all the sewage flows to the plant by gravity. The present resident population of the city is 30,000, and the average sewage volume pumped in 1943 was 3.82 mgd.

The power requirements of the plant fall under the following four general heads: (1) pumping of the raw sewage, a lift of 33 ft. from the wet well to the grit channel, (2) providing compressed air for the activated sludge plant, (3) operation of vacuum filter equipment for removal of digested sludge, and (4) many small motors driving sludge collectors, comminutors, water pumps, sludge pumps, water circulating pumps, etc. The average electric power consumption was 14,990 kwhr. per month in 1943.

Power Plant

Three Climax "Blue Streak" gas engines have been in service since the plant was first started about four years ago. Two of these engines, rated at 75 horsepower, are direct connected to 1800 cfm. Roots Connersville blowers, and the third, rated at 50 horsepower, is direct connected to a 4000 gal. per min. Chicago sewage pump.

Gas production, augmented by the addition of ground garbage to the sewage sludge digesters, has been sufficient to furnish heat for all the buildings and digestion tanks and, at the same time, provide through the means of the gas engines 73 per cent of the total power requirement of the plant. Natural gas, purchased from the private utility company as a stand-by fuel, is piped to each of the three gas engines. By simply turning two valves and adjusting one carburetor screw, the fuel supply may be changed from sewage gas to the 1000 Btu. natural gas, and vice versa.

Heat from the engine cooling jackets and from the exhaust gases is recovered by heat exchangers and used for heating the digesters and plant buildings. Two cooling coils submerged in the aeration tanks provide cooling water temperature control in the summer, when excess heat must be dissipated. All three of the engines are protected by automatic shut-off switches which operate on low oil pressure and/or high water temperature. Automatically controlled signal horns are located in strategic parts of the buildings to warn the plant operators when either of these conditions exist. Electrically driven stand-by pumping equipment, automatically controlled from float switches, is provided for emergency use in case the gas engine unit develops mechanical trouble.

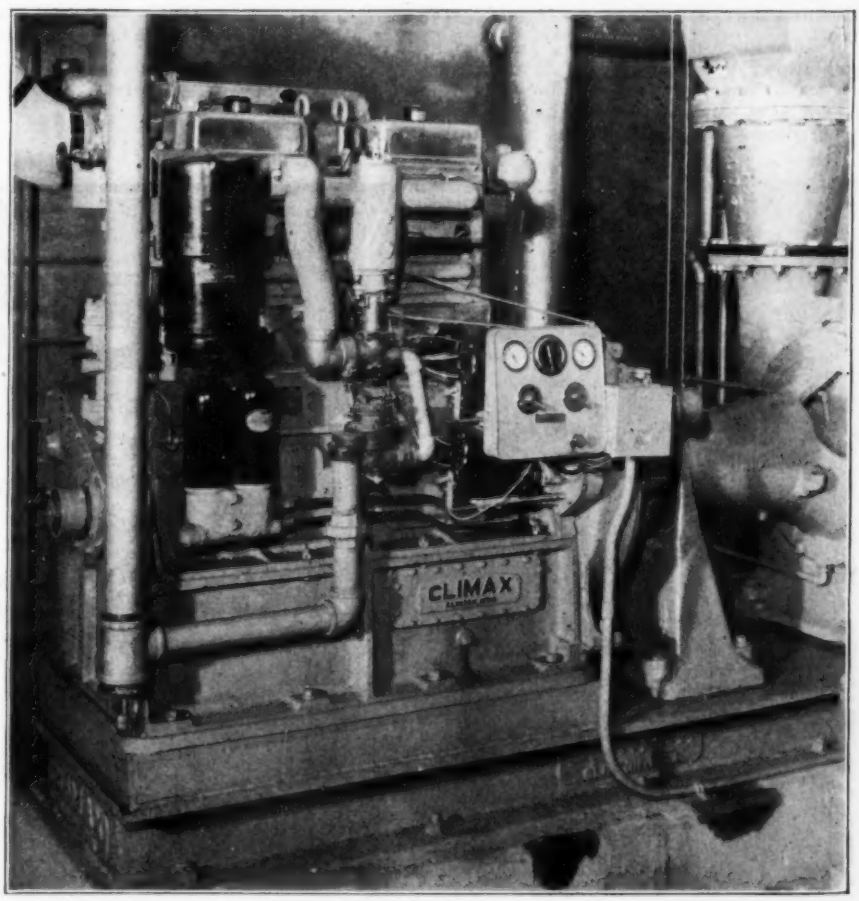
Engine Performance

Inasmuch as the pump engine has operated a greater number of hours than either of the blower engines, its performance record will be reviewed in some detail first. This engine has pumped more than 99 per cent of the sewage treated at the plant to date. It is a four-cylinder Climax engine, having a six-inch bore and seven-inch stroke with a total piston displacement of 792 cu. in. The engine has a rated horsepower of 57.6 with a maximum horsepower of 100 at top speed of 1000 rpm. The crankcase has a capacity of sixteen gallons. Since sewage gas is relatively dry hydrocarbon fuel, a Marvel Mystery inverse oiler is installed to lubricate the upper end of the valve guides and the top edge of the pistons. An industrial oil of S.A.E. No. 35 has been used exclusively in the crankcase. This oil costs 51c per gallon and is purchased from the Gulf Oil Co. A Honan-Crane continuous type oil filter keeps the oil clean and clear at all times. A Gulf Oil product known as Gem Oil "C" is bought at 42c per gallon and has been found to be very satisfactory for use in the inverse top oiler.

Driving the pump by direct connection, the speed of the engine is governed by a float in the raw sewage wet well. Its operation at different speeds for varying sewage flows is, therefore, practically automatic. Since the pump is most efficient at discharge rates close to 4000 gal. per minute, the engine is capable of handling peak flows at times as high as 6.0 mgd.

Maintenance Practice

A maintenance policy, based upon regular periodic inspections of the engines, has been followed. The length of time an engine is operated prior to dismantling and servicing depends upon the condition of the engine after a certain number of hours of continuous operation. Our pump engine was first operated for 8830 hours before it was shut down for overhauling. This period was found to be too long. The piston tops and engine heads were badly carboned; the compression rings were stuck and the oil rings were in such bad condition that they could not possibly function properly. The next inspection was, therefore, made



50-HP. Climax Engine Direct Connected to Chicago Sewage Pump

Muffler and Two Heat Exchangers for Recovery of Gas Engine Heat

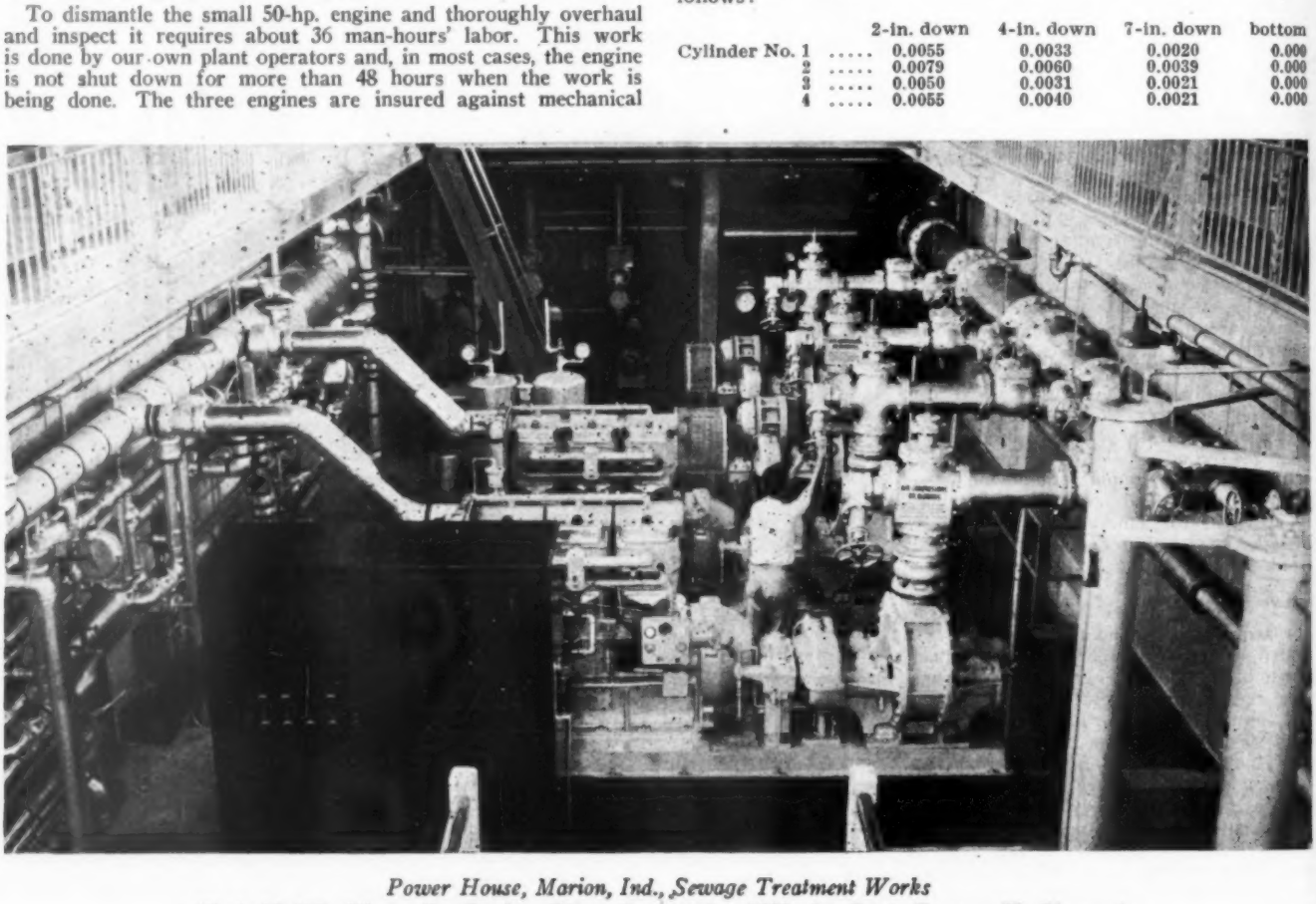
after a continuous run of only 5130 hours. This inspection found the engine in much better condition. The rings were heavily carboned, but were still free and not frozen tight in the grooves as was the case at the time of the previous overhauling. The third overhaul was made after another run of 4310 hours, the fourth after 4720 hours, and the fifth after a run of 5530 hours. It has never been necessary to make a major repair of any kind on this engine in between our regular servicing periods.

To dismantle the small 50-hp. engine and thoroughly overhaul and inspect it requires about 36 man-hours' labor. This work is done by our own plant operators and, in most cases, the engine is not shut down for more than 48 hours when the work is being done. The three engines are insured against mechanical failure of parts while in operation. This insurance covers labor and parts needed for replacement in case of mechanical breakdown. The insurance company sends a trained inspection engineer to the plant to look over the engine each time it is serviced. In accordance with the terms of the insurance contract, recommendations of the inspector as to maintenance policies are carried out by the insured. The insurance cost for the pump engine is $53 per year. We believe this expense is not out of line with the service and protection rendered.

Typical Inspection Report

The following inspection report, made on January 6, 1944, is typical and will give an idea as to what repairs were needed to put the engine in first-class mechanical condition after a run of 5330 hours and a total operation period of 28,544 hours: Engine shut down and completely dismantled for overhauling. Very little carbon found on piston tops and in heads. Engine could have run another month, as all piston rings were free, although oil rings were showing signs of sticking. All three main bearings were opened and one 0.003-inch shim was removed from each side. Rod bearings were carefully inspected and found to be in good condition. All piston rings were replaced by new rings (std. 6-in. by ¼-in. rings used) and all valve springs were replaced by new springs. All valves were replaced by valves that had been re-faced by machining. New valve-seat insert sleeves were put in both intake and exhaust for the first time. All connecting rod bolts were replaced with new bolts (per recommendation of insurance company) as the old bolts had seen more than 25,000 hours of operation. No. 1 cylinder wall showed slight "score" mark from cause unknown. Other three cylinder walls in good shape. Cylinder walls were "miked" for wear as follows:

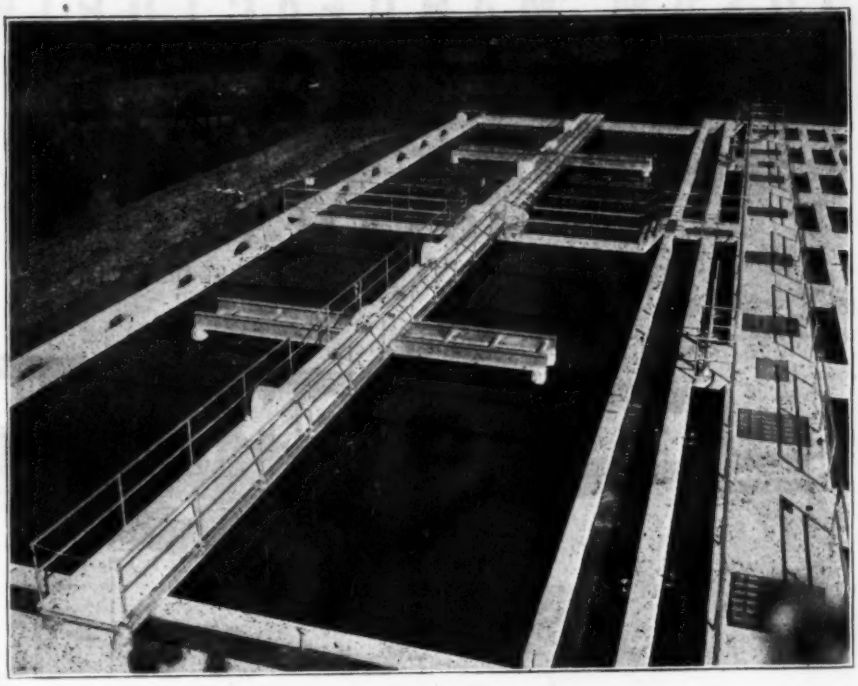
	2-in. down	4-in. down	7-in. down	bottom
Cylinder No. 1	0.0055	0.0033	0.0020	0.000
2	0.0079	0.0060	0.0039	0.000
3	0.0050	0.0031	0.0021	0.000
4	0.0055	0.0040	0.0021	0.000



Power House, Marion, Ind., Sewage Treatment Works
(Twin 75-HP. Climax Gas Engines Direct Connected to 1800 cfm. Roots-Connersville Blowers)

Spark plugs were cleaned and adjusted, and a complete set of new gaskets were used in assembling engine. Crankcase cleaned and flushed—very little sludge found in bottom. New earth cartridge put in Cranite filter, and crankcase filled with new oil. Oil consumption was a little less than one quart per day when engine was shut down for inspection. Oil is used as long as 6000 hours and Cranite filter is changed at 2500 hours.

All of our "Blue Streak" engines are provided with dual ignition systems. American Bosch magnetos are furnished for both the four- and six-cylinder engines. During the first year of operation we had considerable trouble with our magnetos. Only in a very few instances would these units stay on duty for a continuous run of 90 days. Repair costs were quite high, as gear-rotor assemblies were usually needed when an overhauling job was done. At the suggestion of the local American Bosch service headquarters, we purchased one utility magneto for the four-cylinder engine and one for the two six-cylinder engines. We were then able to remove magnetos at regular intervals of sixty days and maintain a strict servicing schedule. Our records show that from August, 1940, to May, 1944, the maintenance cost of the three magnetos used on the pump engine was $207.93, fifty per cent of which was for labor. This gives an average monthly cost of $4.84 for the 43 months operated. The total maintenance cost for the five magnetos used on the larger engines was $293.97, fifty per cent of this total also being for labor. These engines have collectively operated 58 months, giving average monthly cost of $5.05.



Final Settling Tanks, Marion, Ind. (Aeration Tanks on Right)

Dollar Savings

In preparing an estimate of the dollar savings effected by the pump engine, as compared to electrically powered equipment, an operation period of 31,238 hours ending March 31, 1944, was used. The maintenance cost for a seven-month operation period from August, 1941, to March, 1942, was as follows:

Crankcase oil—71 gal.	$ 30.53
Top oil for valves—90 qts.	9.00
Grease for water pump	.50
Re-facing valves	1.60
New piston rings	11.00
Magneto repairs	35.00
Cranite filter cartridges	3.00
Hose and gaskets	5.00
Two sets spark plugs	6.40
Complete set valve springs	5.20
Extra labor—garage mechanic	16.00
Insurance (pro-rated)	31.00
Total	$154.23

To completely overhaul this engine in January, 1944, as previously described, cost a total of $180.15, including insurance charge. Therefore it would be fair to assume the maintenance cost for an average year to be $286.60. (Note—No charge is made for gas purchased from the utility company since this item is more than offset by the value of the heat recovered from the engines.)

The electric utility company agreed to furnish current to the plant at the rate of 1.16c per kwhr., provided the plant was made "all electric" and that no gas engines were installed. To duplicate the work done by the gas engine in pumping the raw sewage would require an estimated 191,000 kwhr. in a twelve-month year. This amount of current would cost $2215.60 at the best electric rates available. The net saving for the pump engine in one year's time is, therefore, $1929.60.

The two larger engines (rated at 75 hp.) driving the air blowers have operated just as efficiently as has the smaller engine. The record of their maintenance cost is parallel to that of the 50-hp. engine in all respects. Due to the variance of the B.O.D. load handled at the plant during the prolonged rainy periods, two blowers are not needed throughout the entire year. Our operation record shows that the blower engines were operated singly for 77 per cent of the time and together 23 per cent of the time during an average year. The average maintenance expense, based on a 5930-hour operation year, for the No. 3 engine amounted to $245.76. The No. 4 engine ran a few less hours, but, since it required the same number of servicings, the cost is also figured at $245.76. The total cost for the blower engines is, therefore, $491.52.

To duplicate the work done by the blower engines in one year would have required an estimated 546,000 kwhr. of electric current. This electricity would have cost $6333.60. The actual savings accomplished by the two engines in furnishing all the air for the activated plant is, therefore, $5842.08. In one year's time the three engines have earned a total of $7771.68. In four years' operation time they will have earned $31,086.72. It is obvious that Marion's city officials made a wise choice in choosing gas engines in preference to electric powered equipment when the plant was being designed.

Some Suggestions

Before concluding, consideration should be given to a few of the mechanical devices and design features that have helped to make our gas engine operation experience a pleasant one to date. Following are some of the more important items:

(1) Engines located in building that has *ample* ventilation.

(2) Plenty of working space around engines so that dismantling is an easy job for the operator.

(3) Provide a tool room and workshop, with cabinet space for stocking replacement parts.

(4) Provide control signals to warn operators when engines are in trouble.

(5) Have a reliable source of stand-by fuel so that engines can be kept in operation continuously.

(6) Install heat recovery facilities of sufficient size so that engine temperatures may be kept constant by automatically controlled valves.

(7) Provide oil filters to keep lubrication at highest possible efficiency.

(8) Have sufficient number of thermometers located in water circulation system so operators can easily check temperature conditions.

(9) Wherever possible, provide duplicate engine-driven equipment for emergency use.

(10) Speed of pump engine should be controlled automatically by float tube from sewage well.

Although no definite post-war plans for further gas engine facilities have been drawn up as yet, it is entirely possible that the Marion plant may be entirely free from all outside power sources at some future date. Sewage gas production approaches the 90,000 cu. ft. per day mark in the summer months, when considerable garbage is being digested. Some days as much as 25,000 cu. ft. of gas is actually wasted. This would point to engine-generator sets being installed with purchased utility gas filling in when sewage gas production does not meet the requirements of the engines. Further operation economies would undoubtedly be accomplished if such a procedure were properly worked out.

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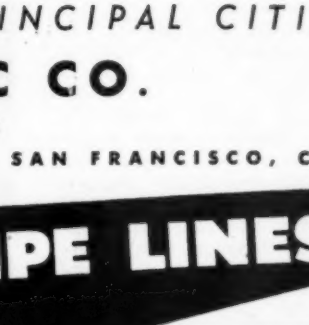
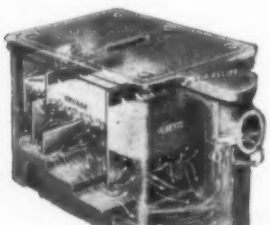


FLAP VALVE Series 1100½

When placed at the discharge end of sewer pipes, the Josam Flap Valve is an absolute safeguard against the backflow of sewage. In sewer lines it can be placed at the manhole. It will also serve as a sluice, river or tide water outlet and can be used between settling basins in sewage disposal plants.



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The Josam Cascade Grease Interceptor provides maximum grease interception and retention for all types of installations. Grease is removed before it clogs drain lines, regardless of the temperature of the water. Made in types and sizes for any requirement.

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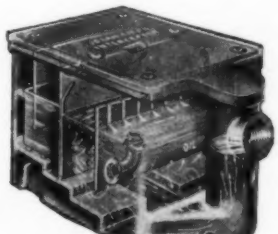

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DESIGN AND OPERATION OF GREASE INTERCEPTORS*

By F. M. DAWSON and A. A. KALINSKE
Iowa Institute of Hydraulic Research

GREASE interceptors (or "grease traps" as they are sometimes called) have been used in plumbing drainage systems for many years. They are frequently required by plumbing regulations, especially for restaurants. In general, such interceptors have been used for one or for all of the following reasons: (1) To prevent clogging of waste lines with grease, (2) to prevent large quantities of grease from reaching the sewage disposal works, (3) to facilitate the reclaiming of grease because of its economic value. The latter reason is, of course, at present a very important one for intercepting all waste grease and fats. The separation of gasoline and oils from waste water is also accomplished by use of a similar type fixture installed in the plumbing system; this paper, however, will be concerned primarily with grease interceptors.

The grease interceptors used at present are for the most part commercial products of various patented designs constructed of cast-iron (ceramic models have been used during the war). If properly installed and serviced, they do a fair job of preventing fats and grease from getting into the sewerage system. Proper installation and servicing, however, is usually the exception. To perform its job properly an interceptor should be installed as close to the fixture discharging greasy wastes as possible, and should be so designed and installed as to be easily cleaned. The less mixing and emulsifying there is, the easier the grease will separate from the waste water. Also the possibility of clogging the drain lines between the fixtures and the interceptor will be prevented if the interceptor is installed near the fixture.

Up until a few years ago the use of grease interceptors, especially in domestic installations, has in general not been overly successful. The interceptors were too small to handle adequately the rate of flow, and the owners did not properly remove the grease which had been collected in the interceptor. If, however, it is desired to separate the grease from the waste water in as complete a manner as possible and also to have the grease in good condition, an interceptor of the proper size installed right at the fixture which discharges greasy waste water is the best solution to the whole problem of grease removal.

Design Principles

A great many types of commercial grease interceptors are and have been on the market and with them many "home-made" designs. The basic principle of grease interception, however, in all such designs is that of gravity-differential separation. That is, the liquid greases and fats separate from the waste water in the interceptor, when the velocity of flow is reduced, owing to the difference in specific gravity.

Gravity-differential separators for liquids are used in many commercial processes, such as, for instance, in the petroleum industry. Of course, so far as grease interceptors are concerned, the problem is complicated by the fact that rarely is it a case of separating pure grease from water. The presence of soaps and food particles increases the difficulty of separation. Of interest in connection with grease-interceptor design is the congealing temperatures and approximate specific gravity of various common fats listed in Table A.

TABLE A

Type of Fat	Congealing Temp. °F.	Specific Gravity
Butter Fat	76-67	0.91
Beef Tallow	88-85	0.90
Mutton Tallow	106-97	0.94
Pork Lard	86-81	0.91

If the interceptor is installed in a kitchen, the temperature will usually be between 80° F. and 90° F. In any case, the discharge of hot water through the interceptor will heat it up, and the time required for passage of greasy wastes through an interceptor will usually not permit congealing to occur. In other words, separation must occur with the grease in a liquid state. Because of the short time it takes for liquids to pass through, cooling interceptors by the use of water jackets is of no consequence, and such interceptors should not be installed because of the danger of having made a direct connection from the pure-water lines to the interceptor, thus producing a potentially dangerous cross-connection.

Since grease separation is due to gravity-differential, a quantitative analysis of what occurs as waste water flows through an interceptor may lead to the establishment of some basic design data. For simplicity let us assume that pure grease and water enter near the bottom of a rectangular-shaped interceptor L feet long, B feet wide, and with a water depth of D feet. The interceptor will do a good job of separation if, as the flow goes through the interceptor, the mean velocity of flow is such as to permit a grease globule to rise a vertical distance D feet in a length of L feet. If we neglect, for a moment, the presence of turbulence we see that the controlling item in the sizing of the interceptor for any particular rate of flow is the rate of rise of the grease globules. If the size of the globules is known, the maximum velocity of rise can be calculated readily from known principles of fluid mechanics, by equating the buoyant force on a globule to the force of fluid resistance. An expression for the terminal velocity of a spherical grease globule is as follows:

$$v = \sqrt{\frac{4d(w - w')g}{3Cw}} \qquad \text{(Eq. 1)}$$

where d is the diameter of the globe, w and w' the unit weights of water and grease respectively, and C a fluid-resistance coefficient, which in texts on fluid mechanics is given as a function of the Reynolds number, which for the globule is vd/ν where ν is the kinematic viscosity of the water, and v the velocity of rise of the globule.

Obviously, the size of the grease globules is an important item. Observations and certain analyses indicate that the design of interceptors should be based on separating out globules of about 0.05 cm. The rate of rise of globules much less than this size is so small that gravitational separation is impracticable, and globules much larger than this will be easily separated. Taking a grease having a specific gravity of 0.90 and the water temperature as 150° F., the rate of rise (v in Eq. 1) of a 0.05 cm. globule is about 0.05 ft. per sec. For a globule of this size the time to rise a vertical distance D is $D/0.05$, and this should be equal to the time of flow for a distance L, which can be expressed as L/V, where V is the mean velocity of flow through the interceptor. We thus have:

$$V = \frac{0.05L}{D} \qquad \text{(Eq. 2)}$$

In most commercial interceptors of rectangular shape, the length is from 1.5 to 2 times the water depth. In that case, according to Eq. (2), the mean water velocity through the interceptor can thus be about 0.08 to 0.10 ft. per sec. Because it is impossible to secure uniform velocity distribution, however, and owing to the presence of some turbulence, the design value of V should not be over one-half of that given by Eq. (2). Modern commercial interceptors having good efficiency check this value of V fairly well.

In all interceptors, the separated grease accumulates in the top of the device and must be removed manually. Naturally, as the grease accumulates, the water-flow cross section decreases and the efficiency of the interceptor soon begins to drop. Some type of baffling is usually necessary and helpful, especially near the inlet. Such an inlet baffle ordinarily has louvers which distribute the flow and give it a gentle upward motion. Many baffles in the interceptor body, however, are undesirable since they induce turbulence. The outlet opening should, of course, be near the bottom at a point farthest from the inlet. Provision should be made for relieving air from the top of the interceptor which is brought down by the incoming flow. In general, to have settleable solids accumulate in a grease interceptor is undesirable. Our plumbing drainage and sewerage systems are designed to carry solids and there is no need of collecting them in a grease interceptor if it can be prevented.

Probably one of the most important design features of a grease interceptor is provision for easy cleaning and removing of accumulated grease. If this is not done, the chances of the interceptor's being properly serviced become remote. The interceptor cover should be light and easily removable, and the grease-accumulation chamber should be free of baffles and partitions which would get in the way during cleaning.

Sizes and Installation

The determining item, so far as grease interceptor size is concerned, is the rate of flow from the fixture or fixtures to which the interceptor is connected. This, of course, requires a

*Presented at the Sixteenth Annual Meeting of the New York State Sewage Works Association, New York City, Jan. 21, 1944. Reprinted from *Sewage Works Journal* by permission of the editor.

knowledge of the rate of flow from various types of plumbing fixtures discharging greasy wastes. If several fixtures are connected to the same interceptor, then some estimate must be made of the probable simultaneous discharge.

Considerable data have been collected on the discharge rate from various fixtures. In Table B is given the recommended minimum rate of flow capacity of any interceptor connected to the fixtures shown:

TABLE B

Type of Fixtures	Rate of Flow in G.P.M.
Small Residence or Apartment Sink	5.0
Large Residence Sink or Dishwasher	10.0
Restaurant Kitchen Sink	15.0
Single Compartment Scullery Sink	20.0
Double Compartment Scullery Sink	25.0
2 Single Compartment Sinks	25.0
2 Double Compartment Sinks	35.0
Dishwashers for Restaurants:	
Up to 30 gal. water capacity	15.0
30 to 50 gal. water capacity	25.0
50 to 100 gal. water capacity	40.0

In addition to its rate-of-flow capacity, a grease interceptor should be rated as to its accumulated-grease capacity. This is the amount of grease in pounds that the interceptor can hold before its average efficiency drops below, say, 90 per cent.

The grease interceptor should be installed, as mentioned before, as near the fixtures as is practical, and its top should be easily accessible for cleaning. The discharge pipe from the interceptor should *always* be vented so as to prevent siphonage of the interceptor contents. This is quite important.

Testing and Rating

In order that interceptors may be properly rated as to capacity, a standard laboratory test is necessary. After years of experience in testing various types of interceptors, investigators have found that various results can be obtained by slight variation of the test procedure. Though field conditions cannot be duplicated in the laboratory, nevertheless the test procedure should have some relation to what the interceptor will experience in the field. A great many test methods have been tried in order to isolate the important items which affect interceptor efficiency. Thus, it has been found that the type and degree of mixing of the liquid grease and the hot water before discharging into the interceptor is an important item. The temperature of the grease and water and grease concentration did not have much effect on the results.

About two years ago, the U. S. Army Engineers, Construction Branch, asked the Iowa Institute of Hydraulic Research to test and rate each type of interceptor that was to be installed in the army cantonments. At that time a standard test was developed which has been used extensively and which seems to give reliable and consistent results. The apparatus used in the tests is shown in Fig. 1.

The hot water for the tests is supplied from a 200-gallon gravity-feed tank which has water and steam connections for controlling water temperature. Below this tank is a calibrated "flow-control" valve, the setting of which determines the rate

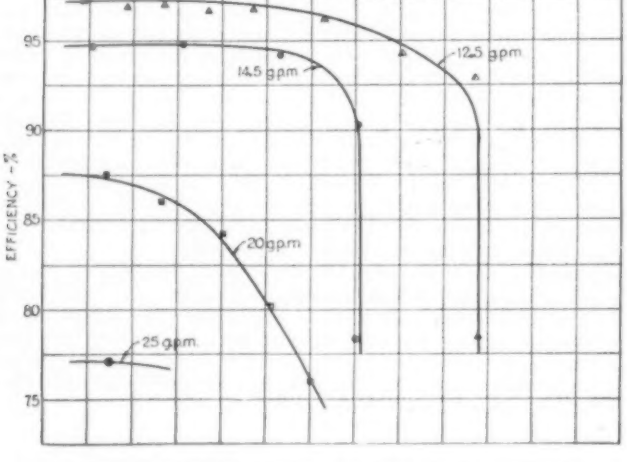


Fig. 2.—Typical laboratory test data for a commercial grease interceptor.

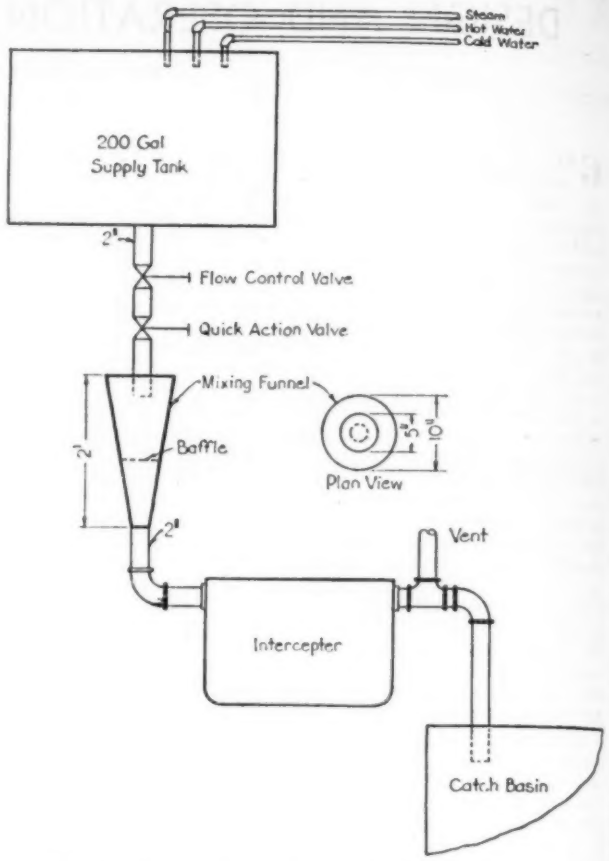


Fig. 1.—Arrangement of apparatus for testing grease interceptors in the laboratory.

of flow. Below this valve is a quick-action valve, which permits quick starting or stopping of the flow. The hot water from the tank discharges into a mixing funnel into which hot grease is poured at a uniform rate during the flow of hot water. The mixing obtained is thus not subject to any manual control. The mixture then discharges into the interceptor. Beyond the interceptor is a large tank from which the grease escaping the interceptor can be caught and skimmed off.

During the discharge of hot water, pure pork lard is added at a concentration of one pound for five gallons of water. This gives a grease concentration of about 2.4 per cent by weight. The water and lard are at a temperature of 150° F. Before starting a run the interceptor is filled with water at 150° F.

A run consists of discharging, at a selected rate of flow, the hot water and grease mixture at a number of two-minute periods. After each two-minute period the grease leaving the interceptor is collected, de-watered, and weighed. For certain large interceptors this collection of escaping grease is made only after two or three discharge periods. The discharging of the mixture of water and grease in two-minute periods is continued until the grease-retaining efficiency of the interceptor drops very appreciably. The average efficiency is calculated as follows:

$$\text{Efficiency} = \frac{(G_i)\ 100}{G_t} \qquad \text{(Eq. 3)}$$

G_t = Total grease in pounds added to interceptor since start of run.

G_i = The pounds of grease actually intercepted; this also equals G_t minus the total grease in pounds that left the interceptor since the start of run.

The foregoing value of efficiency is plotted against total grease in the interceptor, G_i. Thus it is possible to obtain the average grease retaining efficiency of any interceptor from the time it is clean to when a certain amount of grease is accumulated. A typical plotting of test data is shown in Fig. 2.

Authorities have agreed that the average efficiency for the rate of flow at which an interceptor is rated and for its specified grease-retaining capacity should not drop below 90 per cent. Also,

it appeared desirable to have some relation between rate-of-flow and grease-retaining capacity. It appeared reasonable to have the grease-retaining capacity in pounds be at least equal to twice the rate-of-flow rating in gpm. Thus, an interceptor rated at 25 gpm. must be able to retain at least 90 per cent of the grease discharged into it, in accordance with the above described test procedure, until it holds at least 50 lb. of grease. The majority of grease-interceptor manufacturers rate their products in accordance with the above method of testing and rating.

General Comments

Reclamation of grease as near its source as possible is unquestionably the ideal solution to the problem of grease removal from sewage; however, many practical difficulties hinder the working out of this solution in practice. Thus, for instance, the general use of grease interceptors on residential kitchen sinks is of debatable significance. The small amounts of grease usually discharged in kitchen sinks are so mixed with soaps, washing compounds and food wastes that gravity separation in an interceptor is practically impossible. Of course, residential plumbing drains do get clogged with grease, which means, of course, that in certain instances large quantities of pure grease, not emulsified with soap, etc., are discharged into home sinks. In these cases interceptors would be advantageous.

Of course, in the case of restaurant and commercial-type kitchens, the problem is different. Here, inasmuch as large quantities of pure grease and fats are discharged into the sinks, interceptors should always be installed on such fixtures. If, however, the important problem is that of reclaiming grease of high economic value, then it appears that a somewhat different arrangement might be desirable for establishments which have significant amounts of waste grease. In such cases the better procedure would seem to be to have a special fixture available which would be used only for discharging greasy wastes. In other words, all water containing grease and fats would be discharged into a special "separator" which would intercept the relatively pure grease and discharge the water to the sewer. No wash water or soap solutions would be discharged into this fixture. By following this plan much more and much better grease could be salvaged. On a small scale such a method might be used even in homes. However, the success of such grease-salvaging procedures would depend entirely on the public cooperation, and we question whether the American people are sufficiently imbued at present with the need for grease salvaging to carry out any such procedures very extensively.

From certain information which we have been able to obtain, it appears that large quantities of grease are being collected from the interceptors installed in army camp kitchens. Since very few data on actual field operation of grease interceptors are available, it is hoped further definite information about the operation of these interceptors will be obtained as time goes on. These interceptors are of supposedly proper size, and if orders are obeyed they will receive frequent cleaning. Data on their functioning should give an indication as to whether our laboratory testing and rating method is sound. There are good indications that it is, but as always the final proof is "How does it actually perform in practice?"

EXPANSION CHART*

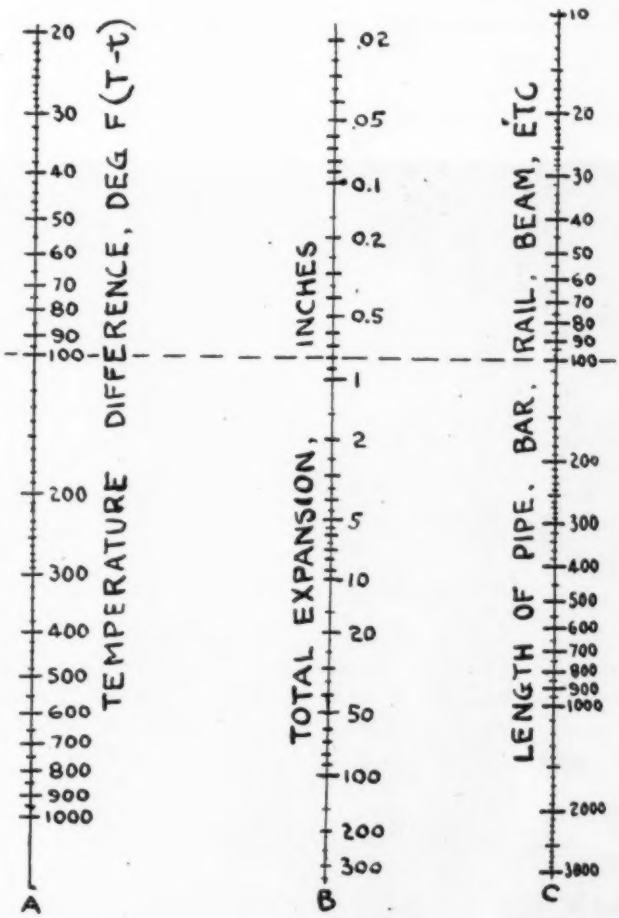
This chart is useful for determining the expansion in piping, rods, tubes, beams, shafts, columns, struts, etc., for any ordinary temperature difference. It makes "longhand figuring" unnecessary. Simply lay a straight-edge across the chart once or stretch a fine black thread across, as indicated by the dotted line, and the problem is solved.

Example: If a certain pipe line 100 ft. long is subjected to a temperature variation of 100 deg. F., what will be the total expansion in inches?

Simply connect the 100 deg. *temperature difference*, column A, with the 100 ft. length, column C. The intersection with column B gives the answer as 0.8 in. That is all there is to it.

The chart can also be used for determining the allowable temperature difference where a definite amount of space is available for expansion and contraction. Thus if the length of the pipe is 100 ft. and the allowable expansion is 0.8 in. the same line would show that a temperature difference of 100 deg. F. would be the limiting amount.

*From an article by W. F. Schaphorst, M.E., Newark, N. J., in WATER WORKS & SEWERAGE, March, 1939.



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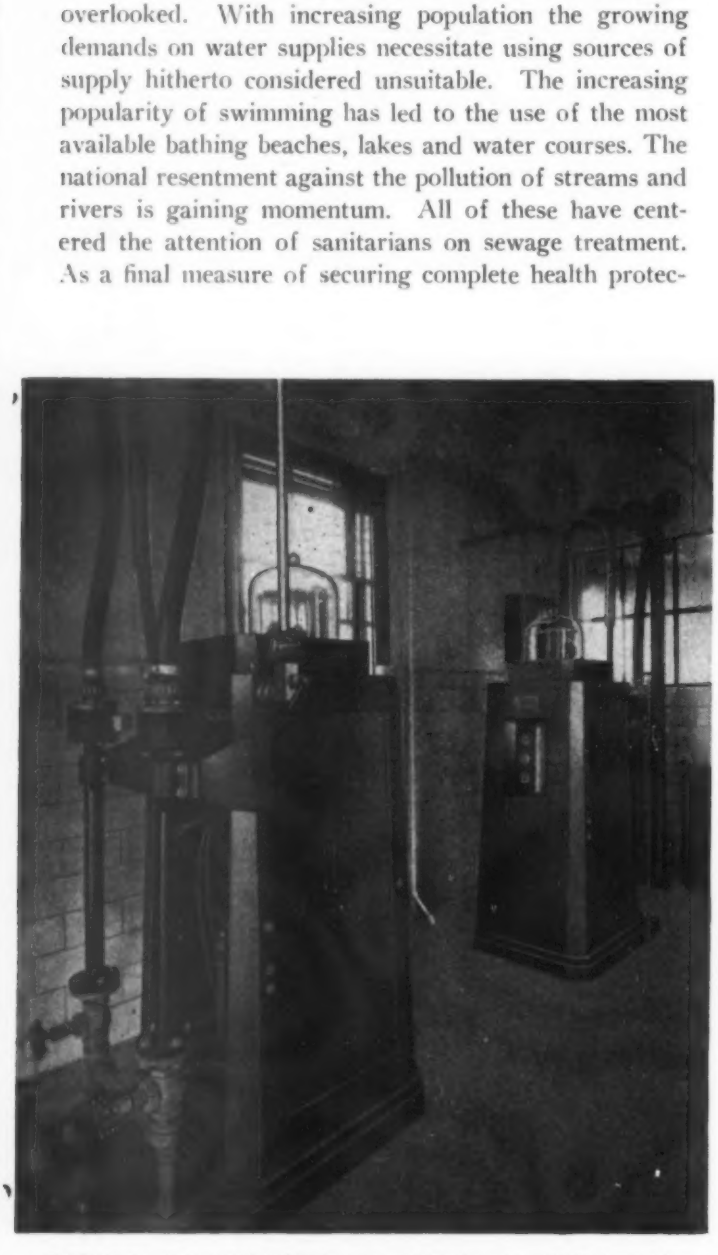
DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.



W&T Master Automatic Visible Vacuum Chlorinators, Stamford, Connecticut, Sewage Treatment Plant.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also satisfactory in results and economy of operation.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of more than 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any specific sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.

CONTROL OF ODOROUS AND DESTRUCTIVE GASES IN SEWERS AND TREATMENT PLANTS

By CHAS. C. HOMMON
Supervisor of Sewage Treatment
Canton, Ohio

THERE are heterogeneous odors from sewers and sewage treatment plants. The so-called sewer gas often referred to in nontechnical language by the layman is not a specific gas. It is an all inclusive term meaning any gas or combination of gases that may be found in a sewer. The most objectionable and far-traveling odorous gases are those originating from stale and septic sewage. Of these volatile compounds, which are expelled from septic sewages, hydrogen sulphide is by far the greatest offender.

This gas, besides creating odor nuisance of intensity and travel distance in proportion to its concentration, has a second and decided objection. It is a dangerously toxic gas in dilution higher than most operators and engineers realize. By authorities it is rated with hydrocyanic acid gas in respect to its toxicity. It is treacherous because individuals working in fatal concentrations lose their sense of smell. Operators working in less than fatal concentration become accustomed to the odor but in time suffer permanent injuries—notably conjunctivitis and respiratory tract inflammation.

Destructive Effects of Sulphide Gas

In addition to the toxicity, hydrogen sulphide is responsible for costly damages to sewers and plant equipment. Copper parts on expensive switchboards and control panels are in short order sulphided and flaked away or crumble to black copper sulphide powder. Short work is made of copper screens and brass work exposed to the moist gas at sewage plants. The first sign is the iridescent blue coloring imparted to copper and its alloys. Hydrogen sulphide can also be easily and simply detected by exposing silver coins for a few hours at points where presence of the sulphide gas may be suspected. The coins turn brown and then black if sulphide gas is present.

Then, one of the most disastrously damaging effects from hydrogen sulphide is its hidden attack. This is the acid disintegration of masonry sewers and all metal parts of manhole structures. The sulphide gas in this type of attack is converted by organisms (bacteria) on the walls of sewers into two acids, sulphurous and sulphuric. It hardly needs be explained that both of these acids make short work of concrete or mortar. The calcium sulphate produced causes rupture of mortar pipe joints and brick sewers or manholes. It has been known to weaken sewers to the point of complete failure of that part above the sewage flow line, below which no damage is done. Therefore, no full flowing sewer is ever damaged by sulphide gas. This gas is never oxidized by organisms which are present in the liquid but only those which thrive in an atmosphere where there exists some oxygen. If, therefore, it were practical to seal sewers so as to prevent all entry of air, there would be no danger of the so-called gas attack of sewers and manholes.

An Instance

The sanitary outfall sewer extending from the southerly city limits of Canton, Ohio, to the treatment plant offers good evidence as to the destructiveness of sulphide gas.

This sewer is 39 inches in diameter, 6.5 miles in length, and was placed in service in 1915. Type of construction was vitrified segment block laid up with mortar joints, and has a theoretical carrying capacity of 18 m.g.d. There is one depressed section, 3,200 feet in length, which is constructed of reinforced concrete. This length of sewer is naturally conducive to septic sewage and consequent development of hydrogen-sulphide, especially during the warmer months of the year. The presence of offensive gases was not particularly grievous with the Imhoff contact bed type of sewage plant that was the original companion unit of this outfall sewer. However, in 1925, when the original contact bed units were converted into trickling filters using the conventional spray nozzles that were in general use at the time, the volatile gases made their presence known through the atomizing effect of the spray nozzles. Thus originated a definite odor problem.

An Early Study in Corrective Treatment

In about 1928 through the efforts and assistance of Mr. L. H. Enslow, associated with The Chlorine Institute, some work was undertaken using liquid to control the odors. The Institute furnished the chlorine and the firm of Wallace and Tiernan loaned the necessary chlorine feeding apparatus for the study.

Chlorine was first added to the sewage at a point locally known as the three way manhole, which is the beginning of the main outfall sewer. This station is 6.5 miles above the Treatment Plant and is the point of convergence of three main trunk sewers.

A number of sampling points were established along the sewer for collecting samples for analysis. It was soon learned that the chlorine would do the trick of controlling the hydrogen-sulphide. However, it was difficult to maintain sufficient chlorine and the required dosage was relatively high. The receding area in the depressed section caused an appreciable increase of hydrogen sulphide which, it was believed, defeated the desired results at the plant. It was obvious that split feeding was the answer; just how many points of desired application were not determined because of the absence of necessary water pressure for operating the chlorine machines at locations below the three-way manhole.

The chlorinators were then moved to the sewage plant and chlorine admitted to the raw sewage just ahead of the bar screens.

This work clearly indicated that a dosage of 10 to 12 p.p.m. would greatly improve conditions at the plant and eventually permanent chlorination equipment was purchased and storage

One of the Early Up-Sewer Chlorinating Stations for Odor Control and Sewer Protection—San Bernardino, Calif. This picture reveals the small space required for such a station and the method of transfer of the one-ton chlorine cylinder from truck to the in-use pit alongside the chlorinator house. Incidentally this picture was taken just after California's worst floods and half-buried the chlorinator house in deposited silt. With the treatment plant put completely out of commission, this station performed an emergency service of disinfection of the bypassed sewage during the restoratiion by merely boosting the chlorine dosage.

racks for handling ton containers of chlorine was constructed. At this time odor control was the all absorbing question, with only minor consideration given to the need for deterring disintegration of the mortar tile joints and concrete structures.

Attack on these, however, became accelerated in the time intervening and the expensive Canton outfall sewer, weakened by joint attack, has ruptured three times in the past few years. Internal pressures, caused from surcharging, proved too much for the weakened joints. These failures offered good reasons and opportunities for a thorough inspection of the sewer and it was found that practically all of the mortar joints above the normal flow line had disintegrated and ceased to exist. Also many of the liner plates were split off and were found lying on the floor of the sewer. It is assumed that the swelling of the mortar in the joints during the sulphating period created sufficient pressure to pinch off the faces of these tile. In a few instances the velocity of the sewage had caused these fallen plates to gather into sufficient piles to develop major restrictions in the sewer. It was interesting to note that the portion of the sewer below the normal flow line was in a very satisfactory condition, no plates missing and all joints normal, whereas the upper areas showed serious attacks. This same condition prevailed in the approaches to the concrete depressed section. Wherever the concrete mortar was submerged it was in a satisfactory condition, but above the normal flow line (those areas normally in contact with moisture and the gases) serious deterioration was evident.

The Original Contact Towers for the Scott-Darcey Process of Making Ferrous and Ferric Chloride at Oklahoma City.

Discharge from chlorinators passes upwards through iron scrap, producing ferrous chloride.

A great deal more is known today about sewage treatment and the handling of sewage than was available when the Canton outfall sewer was constructed and the writer is frank in admitting that he did not fully appreciate what had occurred or what was occurring in the sewer at the time this investigational work was being done. As a matter of fact, there was little if any evidence in 1928 to show that the attack was proceeding at a serious pace, and chlorination at the plant proper seemed adequate for the odor problem.

Methods of Preventing Sulphide Production

Hydrogen sulphide develops only after all other sources of available oxygen utilizable by bacteria have been exhausted. After this, the oxygen hunger of several species of bacteria is satisfied from the only source left—the sulphates. In taking away the oxygen, the residue is sulphide, which hydrolizes into hydrogen sulphide.

Having laid down this premise, it becomes apparent that there are two general methods of preventing or checking sulphate breakdown. These are:

(1) Introducing more oxygen in the form of air, dilution water containing oxygen, or an oxygen containing compound such as nitrate.

(2) Suppression of bacterial activity and multiplication of organisms which deplete the oxygen and eventually break down the sulphates for their oxygen content.

The sewage operator may employ the following corrective methods:

(1) Air blowing to sweep out most of the volatile (free) hydrogen sulphide and discharge of the air-sulphide exhaust through a tall stack. Or absorption of the sulphide in the exhaust may be attained by passing it through an absorption tower.

(2) Destruction of the sulphide in the sewage by addition of chlorine, which precipitates the sulphur *in situ* and deodorizes in so doing.

(3) The fixation of the sulphide by adding a metallic salt such as copper or iron.

These several methods will now be discussed separately.

(1) Oxygen Introduction

Air blowing in the sewer sounds attractive but has many drawbacks of a practical nature. The scheme has never been successfully developed because of structural and operating expense. The effect secured with flash aeration has short duration, as all activated-sludge plant operators will attest. As a matter of fact, a small air input is worse than none in the overall result, since bacterial multiplication is given impetus and oxygen supply is too limited.

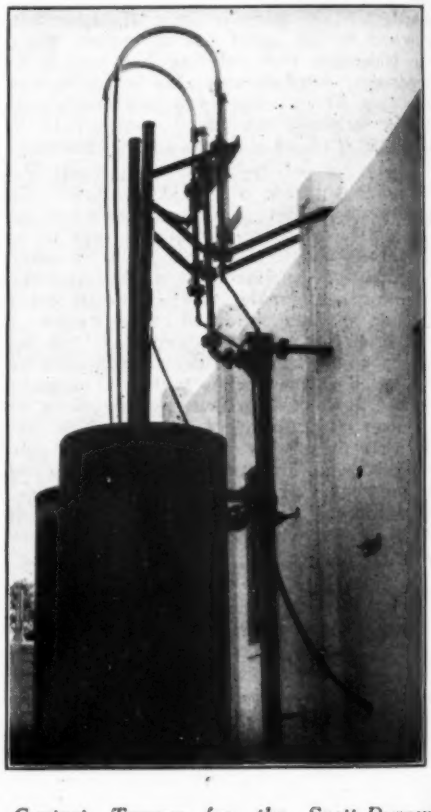
The addition of nitrates (Chilean Saltpeter) has been used; is effective but surprisingly costly in terms of oxygen units provided.

Dilution, by introducing reasonably clean stream water upsewer, has been utilized with excellent results during hot dry-weather flow when the practice is most needed, and fortunately is permissible at such times without surcharging sewers or imposing excessive flows on treatment works. Fortunate is the plant manager who can divert a portion of a stream into his sewer system when most needed to maintain clean sewers, dilute and freshen sewage delivered to the plant at much younger age, and prevent degradation and odor production in the system.

(2) Suppression of Bacterial Activity

In winter, lower temperatures of sewage is the natural suppressor of bio-activity. If it were practical to chill sewage to maintain temperatures of not in excess of 70° F. during its travel through the system there would be no odor or sewer attack problem.

The practical alternative is that of partial disinfection of sewage to reduce the total numbers of organisms, suppress their development, and most important of all, to reduce the biological "turnover." What is meant by "turnover" is the number of new generations of young and vigorous organisms per hour. Like all living things, it is the active youth generation who burn up the oxygen in the vigor of living, and not the grandfather generation. Total numbers of organisms may mean little if anything in sewage. What really counts is the age, activity and species of bacteria. This means much in rate of oxygen utilization and depletion, consequently, the speed of reaching the point of sulphide production and its consequences.



Contact Towers for the Scott-Darcey Process at a Small Treatment Plant in Arizona.

In this instance the chlorinated iron produced is employed for chemical precipitation as well as odor control.

To suppress bacterial "turnover" and rates of oxygen deple-

tion, such as is provided by nature in winter operation, is the basis on which partial disinfection of sewage as close to its point of origin as practical, has met with success. Some remarkable results have thus been obtained with up-sewer chlorination at rates of dosage dictated by the temperature-time factor. In some instances (cooler sewage and short period of travel to the plant) as little as 2 p.p.m. of chlorine has been ample. In other instances (drought and high temperatures with long travel periods to the plant) as much as 12 p.p.m. has been required. In others, a two-point application, between the collecting system and the plant, has been required for higher efficiency and chlorine economy. Taking it by and large, the 5 p.p.m. dosage has been effective when applied sufficiently early—i.e., before bacterial "turnover" has gotten a head-start.

During the past several years "preventative chlorination" has been the most popular odor control measure. No set rule can be given for the dosage needed, for reasons above cited. Nor can a universal specification be written concerning the point (or points) of chlorine introduction up-sewer. Therefore, in cases where doubt exists, a hydrogen sulphide and chlorine-demand survey to determine the most effective application point (or points) is the recommended procedure. As a matter of fact, a portable chlorinator may be employed to determine the permanent location (or locations) for maximum chlorine economy.

In connection with such surveys and chlorination point selection, securing assistance of experienced engineers with The Chlorine Institute, 50 E. 41st St., New York City, or the technical service staff of Wallace & Tiernan Co., and/or of the larger chlorine producers, is suggested.

Other Corrective Methods

In cases where it has not proved practicable to adopt preventative measures, the following corrective methods are available.

(1) Air Blowing at Plant

So far as we are aware, this method has only been utilized at one plant—Dallas, Texas. In a closed chamber the sewage arriving at the treatment works is air-blown for 4 minutes and in the second pass is blown for an additional 4 minutes with air carrying chlorine gas. The exhaust from the aerating and aero-chlorination chamber is discharged through a stack. The plant is also equipped to employ ordinary chlorination or the addition of an iron salt, which will destroy or "fix" the volatile sulphides, as later explained.

(2) Chlorination

By far the greatest number of plants have been equipped for corrective chlorination at the plant proper, when and if odors become a problem. Particularly has this method been mostly adopted for the smaller plants and those where odor nuisance is a possibility rathter than a probability.

In this method, chlorine is applied just ahead of the bar-screens or in the pump well. The dosage varies considerably, running from 2 to 20 p.p.m. of chlorine. In the majority of such cases, the 10 p.p.m. dosage covers the requirement. The practice of pre-chlorination for the dual purpose of disinfection and odor control simultaneously has gained considerable favor in recent times, the largest plants to adopt this method being those of Buffalo, N. Y., and Detroit, Mich., where pre-chlorination has also proved more economical than post-chlorination, and also more effective as a disinfection measure alone.

In the plant chlorination method the sulphide is destroyed by breaking into the compound and precipitating the sulphur thus

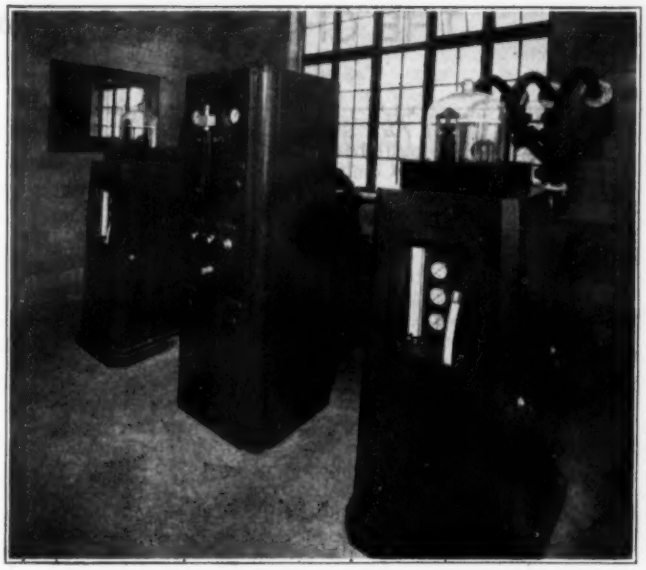
$$H_2S + Cl_2 = 2HCl + S$$

(3) Sulphide Fixation

When adding chlorine *solely* for the purpose of sulphide destruction (i.e., after the sulphide has been produced), the scheme is less effective than the following.

Copper or iron salts may be employed for the purpose of converting volatile sulphide into "fixed" copper or iron sulphide. Since copper is the more costly metal, and since iron chloride can be produced relatively simply and inexpensively on the site of application, this scheme has in recent times become a very popular, effective and inexpensive method.

The iron chloride is produced from scrap iron and chlorine by passing the discharge of a chlorinator upwards through a tank or tower containing the iron scrap. The overflow from the tower is ferrous chloride ($FeCl_2$). The process introduced in Oklahoma City by L. H. Scott, Supt. of Water and Sewage Treatment, and H. J. Darcey, Chief Engr., Oklahoma State Dept. of Health, and known as the Scott-Darcey Process, was taken over and perfected by Wallace & Tiernan Co. In the West and Southwest the method has been rather extensively and effectively used. With the equipment, either iron chlorine or chlorine may be used at will. The equipment can also be operated to produce ferric chloride ($FeCl_3$) for coagulation or sludge filtration at will.



The Triple Purpose Chlorinator Installation at Dallas, Texas The 1,000-lb. capacity dry-feed machine at center is used for "Aero-Chlorination" in grease separation and/or deodorization of stack gas. The two 2,000-lb. capacity solution machines are used for prechlorination odor control or producing chlorinated copperas at will.

In the matter of odor correction, the use of chlorinated iron has many advantages over direct chlorination. For instance, there are stale sewages which when chlorinated partially develop decidedly medicated (iodoformish) odors. This odor is not of a traveling nature but is not pleasant and visitors would object to it. On the other hand, chlorinated iron produces absolutely no odor. For a given amount of chlorine, use of the Scott-Darcey method insures 100 per cent efficiency in respect to theoretical hydrogen sulphide removal per pound of chlorine. The explanation lies in the facf that the iron has affinity only for the sulphide and fixes it completely without organic matter interference, while chlorine is always in part used up by organic matter before it strikes the sulphide. Frequently 50% of the chlorine applied is thus used up and only 50% ever reaches the sulphide.

A fact of considerable interest also is that the iron application can be made at any point desired. If, for instance, it is desirable to add it at the beginning of a long sewer, the iron is used up only as hydrogen sulphide is produced. Therefore, the surplus of iron travels along in contact with the sewage or industrial waste without being depreciated in any degree by the organic content. Thus, the iron becomes available as needed during progress of the sewage between the point of application and the plant. It is plain, therefore, that the chlorinated iron method is a measure of correction which involves the utilization of chlorine to its highest advantage. The method insures an efficiency of hydrogen sulphide removal at essentially 100 per cent of the theoretical, this being the destruction of 1 p.p.m. of H_2S for each 2 p.p.m. of chlorine applied, according to the reaction:

$$H_2S + Cl_2 = 2HCl + S$$

The reactions involved in the chlorinated iron method are:

(1) $Fe + Cl_2 = FeCl_2$

(2) $H_2S + FeCl_2 = 2HCl + FeS$

Since two parts of chlorine by weight accounts for one sulphur, the iron involved can be pictured as a chlorine carrier in the process of "indirect chlorination."

From the above, it is readily observed that the more modern use of chlorine as an agent of controlling hydrogen sulphide would have been of material benefit in preventing failure of Canton's 26 year old outfall sewer, as well as correcting the odor problem at the plant proper. When considering the cost of a large outfall of material length it is apparent that considerable can be spent for Summer time chlorination as a measure for extending the life of such a structure.

THE CHLORINE DEMAND DETERMINATION*

Ed. Note: Although the technic given here was prepared by the AWWA Committee for Chlorination Control of Water, it is suitable for use on sewage providing the operator makes a few minor changes in detail. For example, the size of the sample may have to be varied; the incremental additions of chlorine reagent water will generally be different; the contact time for the determination of the chlorine demand of sewage is standardized at 15 minutes; and 5 portions are usually sufficient.

For sewage, some estimate of the increments of chlorine reagent to be used may be obtained by determining the immediate chlorine demand (I.C.D.), using a spot plate with 1 ml. portions of the sample and 3 drops of ortho-tolidine for ascertaining the residual chlorine, allowing 30 to 45 sec. for color development. (The minimum readable color in the spot plate is between 0.05 and 0.1 pp.)

The I.C.D. may be expected to be from 60 to 80 per cent of the total (15 min.) chlorine demand.

For plant control or field work, the spot plate technic for the determination of residual chlorine is simple and sufficiently accurate, and it obviates the need for standards and apparatus.

THE chlorine demand method presented is designed to lend itself to the determination of the so-called immediate demand or to any other demand using longer contact time or larger chlorine dosages. It can be used, for instance, in the determination of the break-point. It specifies that chlorine water be used as the source of chlorine when liquid chlorine is used in operation. The alternate use of "Zonite" as the source of chlorine, given in Part B, is more convenient for use in the field or when facilities are not available for standardizing chlorine water. Generally speaking, it would appear that results with "Zonite" will be of the same order of accuracy as with chlorine water. It is suitable for use on either water or sewage.

The chlorine demand of water is the difference between the amount of chlorine applied and the amount of residual chlorine remaining at the end of the contact period. The demand for any given water varies with the amount of chlorine applied, time of contact and temperature. For comparative purposes it is imperative that all conditions be stated. The smallest amount of residual chlorine considered at all significant is 0.1 ppm. Treatment of water beyond this point usually results in a series of increasing demands. Addition of that amount which will destroy the ammonia present is commonly termed "break-point" chlorination. In practice, the ratio of chlorine to ammonia nitrogen (NH_3—N) at the break-point is seldom less than 10 to 1 and may reach 25 or more to 1.

All chlorine demands may be determined by following the same general procedure.

Part A. Method for Laboratory Use

Sec. 1—Reagents

1.1. *Ortho-tolidine Reagent—Method 1:* Dissolve 1.35 g. ortho-tolidine dihydrochloride in 500 ml. distilled water. Add this solution, with constant stirring, to 500 ml. dilute hydrochloric acid made by mixing 350 ml. distilled water and 150 ml. concentrated hydrochloric acid (sp.gr. 1.18-1.19).

If it is necessary to use orthotolidine, this reagent should be obtained in the purest possible condition. Even so, ortho-tolidine contains more impurities than the ortho-tolidine dihydrochloride and is therefore less satisfactory.

1.2. *Ortho-tolidine Reagent—Method 2:* Grind 1 g. ortho-tolidine in a mortar with 5 ml. dilute hydrochloric acid, made by adding 150 ml. concentrated hydrochloric acid (sp.gr. 1.18-1.19) to 350 ml. distilled water.

Add 150-200 ml. of distilled water. The ortho-tolidine goes into solution immediately.

Transfer the solution to a 1.0-liter graduate and add the balance (495 ml.) of the dilute acid (A-1.2) and make up to 1.0 liter with distilled water.

1.3. *Storage of Ortho-tolidine Solution:* The ortho-tolidine solution should be: (a) stored in amber bottles or in the dark, (b) protected at all times from direct sunlight, (c) used no longer than six months, (d) kept from contact with rubber and (e) maintained at normal temperatures.

At temperatures less than 0° C., the ortho-tolidine will precipitate from solution and cannot be redissolved easily. The use of the reagent from which part of the ortho-tolidine has precipitated may lead to errors due to a deficiency of ortho-tolidine.

1.4. *Chlorine Water Solution:* A suitable solution may be obtained from the chlorinator solution hose or by bubbling chlorine gas through water obtained from the laboratory tap. Due to instability of chlorine water, it is necessary to make up fresh solutions daily under any conditions.

Standardize the chlorine solution immediately prior to the start of each test. The use of amber bottles is recommended. When hypochlorite is used in plant operation, it may be used for this test.

The strength of the chlorine water or hypochlorite solution should be such that the volume of the treated sample will not be increased by more than 5 per cent.

Standardize the chlorine solution iodometrically (Sec. C-3).

Sec. 2—Procedure

2.1. *Volume of Samples:* Measure at least ten equal portions of the water under test. Use beakers or other glass containers, such as fruit jars, of ample capacity to permit mixing the chlorine with the water. If the object of the test is simply to determine chlorine demand, the volume of the sample in each container may be no more than 100 ml. If the purpose of the test is to relate chlorine demand to bacterial removal, the effect on taste and odor or the chemical constituents of the water, samples of 500 ml. or more will be required.

2.2. *Addition of Chlorine Water:* The amount of chlorine added to the first jar should be such that no chlorine remains at the end of the contact period, especially when low demands are being studied. Add increasing amounts of chlorine to successive portions in the series. The increase between portions may be as low as 0.1 ppm. for determining low demands and up to 1.0 ppm. for exploring higher demands.

Mixing is imperative while the chlorine solution is being added to the sample.

2.3. *Contact Time:* To determine in advance the effect of chlorination, the plant contact time and temperature should be duplicated in the laboratory. For plant control, other and shorter contact periods at some controlled temperature generally can be found. During the contact period, the chlorinated samples must be protected from strong daylight.

2.4. *Examination of Samples:* At the end of the contact period, remove an equal amount from each portion and determine the residual chlorine by either the ortho-tolidine or iodimetric method.

It will aid in studying the results to plot the residual chlorine or the amount consumed.

Samples for bacteriological examination may be removed at desired intervals.

Taste and odor of the treated samples may be observed at ordinary temperatures without de-chlorination. For odor observation at elevated temperatures, samples should be de-chlorinated before heating. Choice of the de-chlorinating agent must be made with due regard to its effect on odor in the water under examination. Generally, sodium bisulfite, using only small excess, is satisfactory.

Part B. Method for Field Use

This test is designed for the measurement of the chlorine demand in the plant or the field when adequate facilities or personnel are not available to employ the more exact method (Part A). Results obtained in this test are approximations only.

Sec. 1—Reagents

1.1. Use ortho-tolidine reagent (Part A, Secs. 1.1 and 1.2).

1.2. *Chlorine Solution:* Use "Zonite." This preparation contains approximately 1 per cent available chlorine by weight. For this test its volumetric measurement is sufficiently accurate.

Sec. 2—Equipment

2.1. One medicine dropper which will deliver 20 drops per ml.
2.2. Ten 1-qt. fruit jars marked at the 500-ml. point.
2.3. Ten 2-oz. bottles marked at the 20-ml. point.
2.4. Glass stirring rod.
2.5. Glass-stemmed thermometer.
2.6 Permanent color standards prepared, as given in the article on the orthotolidine-arsenite test by Gilcreas, or commercially prepared.

*Excerpted from the AWWA Committee Report on "Control of Chlorination" and reprinted by permission of the Association.

Sec. 3—Procedure

3.1. *Measurement of Samples:* Fill each jar to the 500-ml. mark with the water under test. Record temperature at which samples are held.

3.2. *Addition of Chlorine:* While stirring constantly, add 1 drop "Zonite" to water in the first fruit jar, 2 drops to that in the second jar, 3 drops to that in the third jar, etc. Each drop of "Zonite" represents a chlorine dose of 1.0 ppm.

3.3. *Contact Time:* The contact time is a variable factor depending entirely on the results desired. Generally, the purpose of a chlorine demand test is to determine the amount of chlorine required to produce a definite residual after a definite time interval.

It is recommended, therefore, that the testing be carried out at the end of the contact period corresponding to the contact at the point of control. This may vary all the way from a few minutes to several hours. Under some circumstances it is desirable to make several chlorine determinations at different times of contact, such as 15, 30, 60 min., etc. Such a procedure will give an indication of the stability of the chlorine as related to time, which will be very useful information in plant control.

The time of contact must be recorded. During the contact period the chlorinated samples must be protected from strong daylight.

3.4. *Examination of Samples:* At the end of the contact period, remove a 20-ml. portion from each sample, place it in a 2-oz. bottle and add 1 ml. ortho-tolidine to each 20 ml. Determine residual chlorine by comparison with permanent standards.

3.5. *Calculation:* Subtract the amount of residual chlorine (in ppm.) found in examination of samples from the amount of chlorine added (in ppm.). The result will be the chlorine demand (in ppm.) of the sample at the respective dosage, contact time and temperature. Plotting the residual chlorine or the amount consumed will aid in studying the results.

Part C. Iodometric Method for Residual Chlorine

The iodometric method for the determination of residual chlorine in water can be made more precise than the ortho-tolidine method, particularly when residual chlorine is greater than 1 ppm. When the titration is made without acid, the interfering effect of nitrites and manganic and ferric salts is minimized. Generally, the starch-iodide method carried out in acid solution yields higher figures than the neutral starch-iodide titration. The acid titration therefore is preferred when interfering substances are known to be absent. Acetic acid should be used, but if not available, sulfuric acid of cp. quality may be substituted. *Hydrochloric acid should not be used.*

Colorimetric methods for the iodometric determination of chlorine are available, but are not given in this report.

Sec. 1—Reagents

1.1. *Potassium Iodide Solution (KI):* Dissolve 75 g. cp. potassium iodide (free from iodine and iodate) in 1.0 liter freshly boiled and cooled distilled water. If difficulty is experienced with stability of the solution, the solid substance may be used directly, since it is very soluble.

1.2. *0.01N Sodium Thiosulfate:* Stability of 0.01*N* thiosulfate is improved if it is prepared by diluting an aged 0.1*N* solution (made as directed in Part C, Sec. 1.2.1) with freshly boiled distilled water. Boiled water is used because bacterial action decomposes 0.01*N* thiosulfate. Trouble of this sort may be avoided by the addition of a few milliliters of chloroform. For accurate work, this solution should be standardized daily. The use of an automatic burette, of a type in which rubber does not come in contact with the solution, is advisable.

1.2.1. *0.1N Sodium Thiosulfate:* Make 0.1*N* sodium thiosulfate by dissolving at least 25 g. of the cp. salt in 1.0 liter of freshly boiled distilled water, standardizing it against potassium dichromate, after at least two weeks' storage.

1.3. *Starch Solution:* To 5 g. starch (potato, arrowroot or soluble) in a mortar, add a little cold water and grind to a thin paste. Pour into 1 liter of boiling distilled water, stir and allow to settle overnight. Use the clear supernatant. The solution should be preserved with salicylic acid (1.25 g. per liter of starch solution). The starch may also be preserved with zinc chloride added at the rate of 4 g. per liter.

1.4. *Acid Solution:* Use either (a) a solution of acetic acid, made by diluting 500 ml. glacial acetic acid to 1.0 liter with distilled water, or (b) a solution of sulfuric acid, made by adding 20 ml. of concentrated sulfuric acid (sp. gr. 1.84) to approximately 750 ml. distilled water and diluting to 1.0 liter. Add the acid to the water slowly, with constant stirring.

Sec. 2—Procedure

2.1. *Volume of Sample:* The amount of sample to be taken for titration is governed by the concentration of chlorine in the sample. It is suggested that, for quantities of residual chlorine of 1.0 ppm. or less, 1.0 liter be titrated; for residual chlorine concentrations between 1 ppm. and 10 ppm., 500 ml.; for residual chlorine concentrations above 10 ppm., proportionately less of the sample should be used. It is preferable to use sufficient sample so that not more than 20 ml. of 0.01*N* thiosulfate is required.

2.1.1. *Preparation for Titration:* If no interfering substances are present, place 10 ml. acid, or sufficient to reduce the pH to between 3.0 and 4.0, in a flask or white porcelain casserole, add 10 ml. of KI solution, pour in the sample and mix with a stirring rod. Omit the acid if interfering substances are present.

2.1.2. *Titration:* Add 0.01*N* thiosulfate from a burette until the yellow color of the liberated iodine is almost discharged. When liter samples are titrated, add 5 ml. starch, reducing this amount with smaller samples. The amount of starch used should be sufficient to give a deep blue color. After the addition of starch, titrate carefully, but rapidly, to the end-point. Long contact of iodine and starch produces a blue compound which is decolorized with difficulty.

2.2. *Calculation of Results:* The number of milliliters of 0.01*N* thiosulfate used in 1.0 liter of sample multiplied by 0.3546 equals the chlorine present, in parts per million.

Sec. 3—Standardization of Chlorine Solution

3.1. *Volume of Sample:* In standardizing the chlorine solution for temporary standards, the volume taken for titration should be such as to require not more than 20 ml. 0.01*N* thiosulfate.

In standardizing chlorine water solution (Part A, Section 1.4) for determining chlorine demand, the volume taken for titration should be such as to require not more than 20 ml. of 0.1*N* thiosulfate.

3.1.1. *Preparation for Titration:* Proceed as in Part B, Sec. 2.1.1. Distilled water may be added at the discretion of the analyst if a larger volume is preferred for titration.

3.1.2. *Titration:* Titrate the chlorine solution as in Part B, Sec. 2.1.2.

3.2. *Calculation of Results:* In standardizing chlorine solution for temporary standards:

$$\text{mg./ml. chlorine} = \frac{\text{ml. 0.01 } N \text{ thiosulfate} \times 0.3546}{\text{ml. sample titrated}}$$

In standardizing chlorine water solution for determining chlorine demand:

$$\text{mg./ml. chlorine} = \frac{\text{ml. 0.1 } N \text{ thiosulfate} \times 3.546}{\text{ml. sample titrated}}$$

References

AWWA Committee: Report on Control of Chlorination. *JAWWA* 35, 1315 (1943).

KEEPING LIME SOLUTION LINES CLEAN

To retard building up of incrustation and depoits, which choke pipe lines conveying lime suspension, the following has been found very helpful at the Richmond, Va., Filter Plant. A program clock at 4 hour intervals opens and closes a flushing valve connected into the line at the inlet end. The line is thereby automatically scoured free of the loosely deposited carbonate and hydrate 6 times daily.

If a scale gradually builds up which the Richmond scheme of water scour will not remove, chlorine water from a chlorinator can be run through for the required period to dissolve or loosen the scale. Chlorine water applied to lime carbonate reacts to produce hypochlorous acid, carbon dioxide and calcium chloride as indicated by the reaction,

$$CaCO_3 + H_2O + 4\,Cl = 2\,HO\,Cl + CaCl_2 + CO_2$$

Pouring chlorine water slowly through a column of ground limestone or marble will demonstrate the reaction and is a well known method of preparing hypochlorous acid. The solution resulting, because of the weakness of the hypochlorous acid produced, has a pH of 8.0 to 8.2.

After the carbonate is all converted, chlorine water will naturally attack metallic solution lines. Lines of rubber hose with jointing made by butting hose ends together *inside* of a short sleeve of larger size hose, or a short section of pipe, provides a very satisfactory all purpose chemical feed line.

PENNSYLVANIA SALT MANUFACTURING COMPANY

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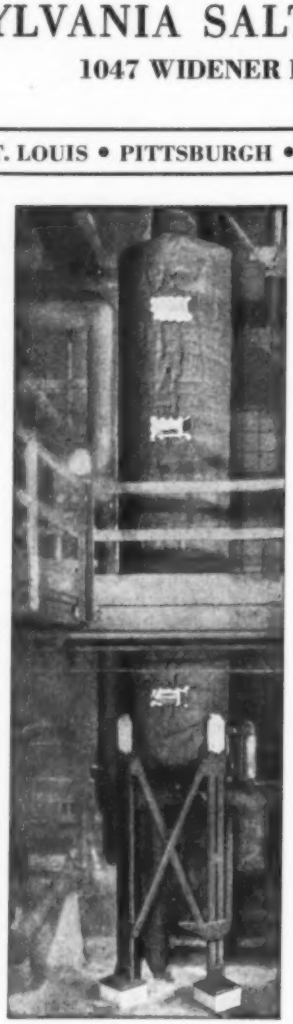
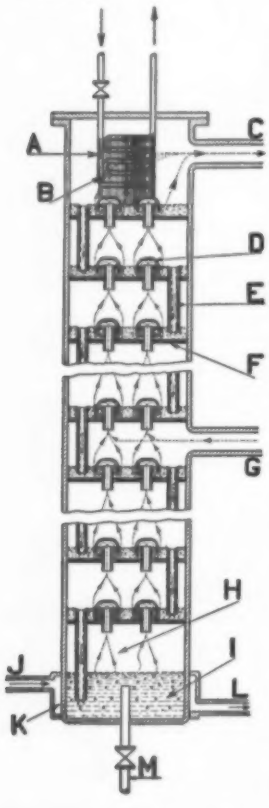
• LIQUID CHLORINE

A clean amber-colored liquid about one and one-half times as heavy as water. Supplied in steel containers which are under pressure at temperatures above 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being about 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is about two and one-half times as heavy as air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.





Operating Diagram of the Chlorine Fractionating Column

A. Refrigerating Coil
B. Condensing purified chlorine
C. Purified chlorine outlet
D. Bubble cap
E. Downtake for reflux
F. Tray or plate
G. Raw chlorine inlet
H. Chloroform vapors
I. Chloroform and dissolved impurities
J. Steam inlet
K. Heating jacket
L. Condensed water
M. Drain for impurities

Chlorine has been proved to be the most efficient, flexible and economical agent for sterilizing water supplies; and it is also used as a sludge stabilizer, a taste and odor eliminator, a precipitating aid, and, in sewage treatment, for disinfection, for B.O.D. reduction and odor control. The quantity of chlorine required in water purification and sewage treatment processes depends upon the quality of water, the point of application, and the object desired. Penn Salt Liquid Chlorine is particularly adapted for such processes because of its high purity and freedom from objectionable "taffy" or chlorine gum, achieved by means of the specially designed Penn Salt fractionating column which eliminates practically all harmful impurities from the chlorine.

This Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with requirements of the Interstate Commerce Commission concerning specifications, retesting, loading, maintenance. Liquid Chlorine is also shipped in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes, 32,000 and 60,000-lb. respectively. The care with which all Pennsylvania Salt packages are cleaned and double-checked, coupled with the quality of Penn Salt Liquid Chlorine, assure maximum safety and convenience in chlorinator operation.

• PERCHLORON

Per*chlor*on is a high strength calcium hypochlorite, having a guaranteed active ingredient of not less than 70% calcium hypochlorite or available chlorine. It is free flowing, concentrated and retains its labeled strength for one year or more under normal storage conditions. It weighs approximately 52.5 pounds per cubic foot. It is composed of finely divided particles, all of which will pass a 20 mesh screen and be retained on a 65 mesh screen. It is quickly soluble in water, and is useful as a second line of defense for water purification in cases of emergency, when supplies of liquid chlorine may be temporarily cut off. Per*chlor*on is also used for sterilizing new mains, as well as clear wells and filters; valuable for sewage treatment, too. Many leading swimming pools sanitize their water with Per*chlor*on, use it to combat slime and algae growths, and to control athlete's foot by means of trays and spraying locker and washrooms. Per*chlor*on is supplied in handy-sized cans equipped with Kork-N-Seal covers, 9—5-lb. cans to the case. Also in 100-lb. drums.

• AMMONIA, Anhydrous

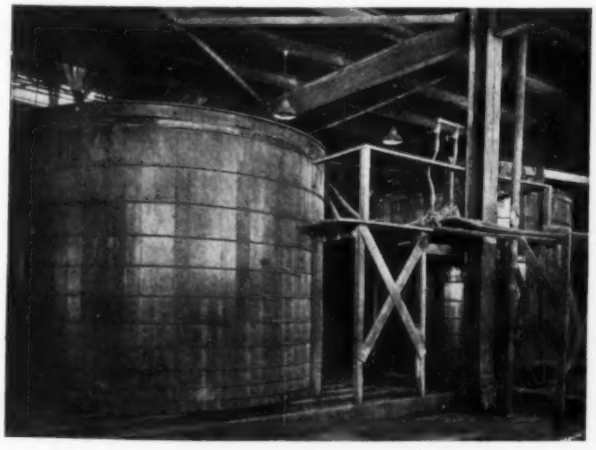
A colorless liquid which at 70° F. is 0.61 times as heavy as water, and weighs 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F., 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

This characteristic of ammonia is utilized in the dry feed ammoniators in water works. It is also useful in the chloramine process, in which ammonia is applied along with chlorine to prevent the formation of chlorinous, phenolic or medicinal tastes; and for stabilizing or prolonging the sterilizing action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, with points of application ranging over the entire purification process. To prevent taste intensification, the ammonia must be applied before the chlorine.

Pennsylvania Salt Anhydrous Ammonia is supplied in special improved cylinders of seamless drawn steel which are light, strong and easy to handle and store. Gas may be withdrawn either with a cylinder standing upright on a scale for weighing, or with the cylinder lying horizontal, whichever is most convenient.

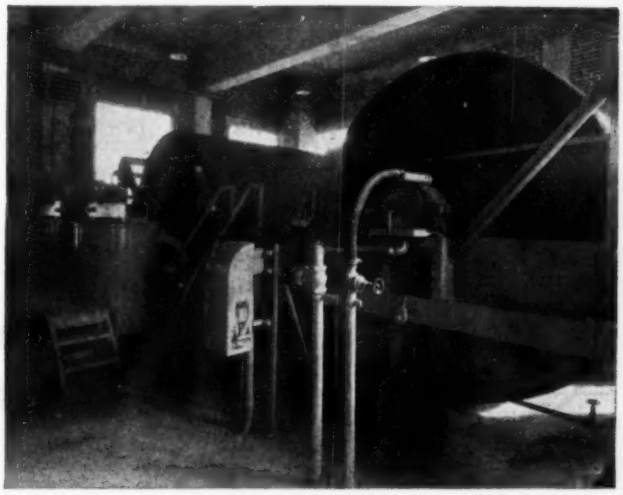
• FILTER ALUM (Sulphate of Alumina)

This product is the principal coagulant used in water purification; and Penn Salt, Commercial or Iron Free Alum has been adopted by many water works superintendents and engineers. Available in any quantity from a single bag or barrel to carload lots. Bags and barrels are paper lined as a protection against atmospheric moisture.



• FERRIC CHLORIDE

In liquid form it is an aqueous solution, the concentration of which is governed by the outside temperature and varies from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Pennsylvania Salt also supplies ferric chloride in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as is permitted by impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most communities, depending upon shipping costs, ferric chloride offers vast savings over alum. The aqueous solution is shipped in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. Anhydrous ferric chloride is shipped in non-returnable steel drums, 150 and 400 lb. sizes.



• SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda, used both for softening water and as a combined coagulant and softener. Most effective in water requiring an alkali with the alum. Shipped in steel non-returnable drums, net weight 100 and 400 lb. each; and in 100-lb. moisture-proof burlap bags.

• SODA ASH
CHLORIDE OF LIME, and
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are among the other chemicals made by Pennsylvania Salt and used in water purification and sewage treatment. Ask us for detailed information and expert technical assistance.

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Ferri-Cl_3or
Ferric Chloride
The FAST Coagulant

AS A COAGULANT FOR SEWAGE AND INDUSTRIAL WASTES

The chemical treatment of sewage and industrial wastes is an effective and economical method of increasing the efficiency of the ordinary sedimentation plant. Such treatment requires but little plant construction or capital investment. It provides a high overload capacity and flexibility in proportioning to produce the degree of purification required. Seasonal loads are readily handled with the Ferri-Cl_3or treatment.

Ferri-Cl_3or coagulates sewage and industrial wastes, thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that Ferri-Cl_3or is also an *economical* coagulant for sewage and a wide range of industrial wastes.

FOR COAGULATING SEWAGE

Ferri-Cl_3or provides an inexpensive and efficient method of dealing with plant overloads, and reduces original plant investment by increasing the capacity of the sedimentation plant.

AMOUNT of Ferri-Cl_3or to be Used

The accepted procedure in determining the dose of Ferri-Cl_3or required to coagulate a given sewage is to set up "jar tests" with sewage to be tested. 2 qt. Mason Jars and stock solutions of Ferri-Cl_3or and lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several Mason Jars. Add to the sewage in each jar, successively larger doses of Ferri-Cl_3or stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for Ferri-Cl_3or. The amount in lbs. of Ferri-Cl_3or or lime required equals the number of c.c. used in the selected test x 10 x total sewage flow (m.g.d.) x 8.33.

ISCO FERRIC CHLORIDE

FOR SLUDGE CONDITIONING

For efficiency and economy—ISCO Ferri-Cl_3or produces the best sludge floc for filtration, compared weight for weight with other commercial coagulants. Because of this fact, ISCO Ferri-Cl_3or is accepted as the lowest-cost powerful sludge coagulant on the market.

AMOUNT of Ferri-Cl_3or to be Used

Using the Buchner Funnel Test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. 2 to 3 minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held, as in batch-mixing.

Various combinations of Ferri-Cl_3or and lime should be tested until the relative quantities for optimum operation are determined. The approximate quantities of chemical to be used in the plant can be determined from the laboratory test, provided, of course, that the same strength chemicals are used in the plant. The quantity of Ferri-Cl_3 or solution in gallons per 1,000 gallons of sludge will be 5 times the c.c. used per 200 c.c. of sludge in the test. Likewise, the quantity of lime in pounds per 1,000 gallons of sludge will be 42 times the grams used per 200 c.c. of sludge.

PREPARATION of Ferri-Cl_3or Solution

Saturated solutions of Ferri-Cl_3or are heavier than water, i.e.: you may have clear water above and undissolved crystals at the bottom of your mixing tank. Therefore, we recommend dissolving by one of the following effective and efficient methods:

1. Automatic gravity circulation by placing the salt on a wooden grid elevated or suspended one-half way in the tank.

2. Mechanical mixing by (a) stirring, (b) air agitation, and (c) liquid recirculation.

3. Melting: Ferri-Cl_3or melts at 98.6 to 102.2°F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

Ferri-Cl_3or
Ferric Chloride
Ferric Chloride 60% ($FeCl_3$)

is ISCO's registered name for Ferric Chloride developed and manufactured especially for Sewage and Water Treatment.

PROBLEMS IN HANDLING SEWAGE SLUDGE

By CHARLES R. VELZY
Greeley & Hansen, Engineers., New York City

THE disposal of sludge has always been one of the major problems of sewage treatment. It is not in itself a primary objective of treatment. It adds materially to construction and operating costs, and the preparation of the solids for final disposal is fraught with many difficulties. It has been a necessary evil, rather than an asset.

Sludge handling problems differ according to the type of sludge, and the magnitude of the difficulties varies as widely as the characteristics of the material being handled. Activated sludge is liquid and homogenous, and presents few mechanical or hydraulic problems. Primary sludge, on the other hand, is of lower moisture content, contains solids which are coarser and partly of a fibrous nature, and usually carries grease in an amount to be troublesome. Its characteristics cover a range from a relatively freely flowing heavy liquid to a semi-solid which refuses to move under the action of a positive displacement pump and the coaxing of a skillful operator. A mixture of activated and primary sludge may show characteristics anywhere between these extremes. This discussion relates to the problems encountered in handling sludge having the more stubborn characteristics.

At least two of the "gremlins" plaguing the sludge operator can be identified and are well known. They are the trash or ground screenings which come through the settling tanks, and the grease which is usually handled with the sludge. The troubles caused by these materials have led to the suggestion that they should not be returned to the sludge when once removed from the sewage. It is often found, however, that disposal with the sludge is less troublesome than separate disposal and the problems related to and aggravated by these materials are therefore frequently encountered.

Trouble from screenings may be reduced by attention to a number of details in plant design and operation. Screenings may be designed with relatively close bar spacing (¾ inch or 1 inch), and the grinder may be arranged to discharge the ground screenings on the upstream side of the screen. Some of the coarser material passing the grinder is thus caught again and reground. It is obvious that the grinder should be kept in good condition, particularly to minimize the passing of long fibrous material.

In a treatment works where large quantities of leaves and other trash are likely to accompany or follow a storm, it may be advantageous to provide for by-passing the grinder to keep the screenings out of settling tanks at times of heavy load. The elimination of what might constitute a "slug" of clogging material is worth while, and since the screenings at such times are relatively clean, separate disposal is not too difficult.

Grease is difficult to handle wherever it is found. Skimmings from a settling tank require mixing with large quantities of water. The water must be largely separated for economical pumping, but if separation is too complete the grease "cakes" and cannot be pumped. It tends to congeal in pipe lines, and in a sludge tank it floats and adds to the burden of control of top sludge or scum.

These problems are being minimized at some plants during the war by salvaging the grease. The skimmings from the primary settling tanks are removed and sold. Operators at these plants report appreciable reduction in grease troubles in pipe lines and in quantity of floating material in sludge tanks.

For the sake of discussion, the problems in handling sludge from the time it leaves the settling tanks until it is ready to leave the sludge tanks are classified into four categories, as follows: (1) pumping problems, (2) troubles encountered in pipe lines, (3) metering, and (4) problems in the sludge tanks.

Pumping Problems

Discussion of sludge pumping always leads to consideration of types of sludge pumps. The competition between the displacement pump and the "screw-feed" centrifugal pump will probably continue for some time. In discussing their relative merits, one plant superintendent once said that he thought an operator having both types available would always use the centrifugal so long as it was effective, because it was simple and clean to operate and required a minimum of maintenance. For high suction lift or for discharge pressure above normal, however, the displacement pump is better adapted. In a plant recently built, where two sludge pumps were needed, one of each was specified in order to cover a wide range of sludge characteristics and also to obtain the advantages of both types of pump.

It has been stated that a displacement pump operates better with some suction lift than with pressure on the suction side. However, the need for minimum length of pipe and the fewest possible bends in the suction lines often points to placing the pumps below the water level of settling tanks. Some pressure in the line also is an aid in keeping the line clear of gas. The designer must weigh these and other factors in each plant design and adopt a layout best fitting the conditions.

Considerable uncertainty is involved in determining the operating pressure for which sludge pumps should be designed. It is a problem which does not conform to hydraulic formulas, and the answer must, therefore, be derived from experience and judgment. Particularly in larger plants, pressures sometimes build up rapidly or a stoppage results in a sudden increase in pressure. A pump which will withstand and operate under a pressure of 50 pounds per square inch will suffer much less interruption than one designed for only 50 feet of head. At New York City it has been the practice to install in each primary sludge pumping station a high pressure pump for emergency use, which is capable of operation at 100 pounds per square inch.

At Buffalo the primary sludge pumps specified and built for a working pressure of 50 feet proved to be too light. Breakage occurred in connecting rods, packing gland bolts and in pump body castings. The pumps have been modified, the alterations including new connecting rods, smaller diameter cylinders and plungers, heavier castings and some other changes. Less interruption to operation has been reported.

The variable pressure, wide range in sludge characteristics, and the general severity of the service have led to more sturdy pump design. An example of later design is the triplex plunger pump with variable speed gear drive. (See Fig. 1.) It has a number of advantages over the duplex plunger pump with variable stroke. Added capacity is obtained without excessive velocity through valves, full stroke at low pumping rates results in less slippage than shortening the stroke, and there is always a more uniform velocity in the discharge pipe.

The summation of these factors calls for a pump of more rugged construction and better and more expensive mechanical parts than was acceptable some years ago. Manufacturers are meeting this requirement, and designing engineers should adjust specifications as necessary to call for the better type of pump where it is needed.

The maintenance on sludge pumps must be expected to be high. Wear on packing and plungers is rapid, and frequent renewal of packing is necessary. For plunger pumps, most operators experiment with several types of packing until one is found that lasts longer than other types. It is difficult to select any make or style of packing as best for all applications, but it is suggested that resilience and resistance to abrasion are two characteristics to be sought.

Relatively frequent restoration of plunger surface is also required. This can be accomplished by installing new plungers. It may be worth while using a plunger with a thick wall so that refinishing can be done one or more times before discarding the plunger. The added clearance resulting from refinishing can be taken up with thicker packing or a shim in the outside of the packing space.

Every operator is familiar with the problem of maintaining cleanliness in a sludge pumping station, particularly where plunger pumps are used. Leaking packing, drawing of samples and cleaning of valves, all contribute to the difficulty of keeping the station clean. Pump bases are usually provided with a lip or curb and a drain to carry off the leakage from the pump, but with sludge this is not effective. Solids from the sludge tend to accumulate within the curb and to clog the drain. Since cleaning must be a continuous and a routine operation of flushing and wiping, it may be helpful to fill the drainage spaces and channels in the pump base to prevent accumulation of dirt.

At the joint meeting sewage treatment plant of Essex and Union Counties, New Jersey, each sludge pump is enclosed within a concrete curb. As explained by E. P. Decher, acting chief engineer, this keeps the spilling of sludge "within bounds" and makes it possible to flush around the pump after cleaning valves and the like, without splashing the rest of the station floor.

In addition to thorough cleaning, Mr. Decher offers the suggestion of burning a small amount of sandal wood to overcome any lurking odors of sludge. A recent visit to the plant demonstrated the effectiveness of this "stunt." It should, of course, be borne in mind that the burning of incense is not a substitute for cleanliness, and the immaculate condition of the joint meeting plant shows that there is no improper use there. This may

be worth remembering as a final touch to the preparations for the visit by the Women's Club or the mayor and his committee.

Piping

There has been some difference of opinion regarding the selection of pipe sizes for sludge. One line of reasoning calls for large sizes and low velocity in order to keep friction losses to a minimum, particularly when the sludge is heavy. The other reasoning calls for relatively small lines and higher velocity in an effort to prevent deposits and the congealing of grease on the walls of the pipe. With the differences in sludge characteristics and other conditions in the various plants, it is difficult to make a definite determination on this point.

In recent years operators have reported a number of cases in which grease has been found to accumulate on the walls of the pipe to greatly increase friction losses, or actually to produce stoppage in the pipe lines. In many of these cases pressures have not been excessive except as the grease has accumulated in thickness sufficient to greatly reduce effective diameter. It therefore appears that a reasonable velocity in the sludge line will not cause excessive pressure, unless the line is partly plugged. When a line is partially plugged it is best that it be cleaned and normal operating conditions thus restored.

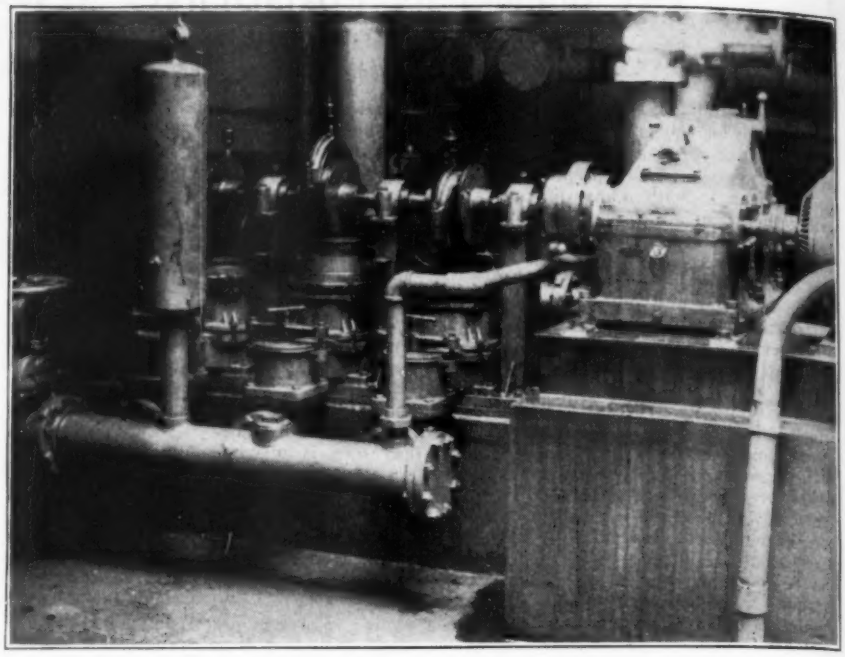

Fig. 1—Triplex Plunger Pump with Variable Speed Gear Drive

A part, if not all, of the trouble of grease accumulation in sludge lines appears to result from the pumping of primary settling tank scum through these lines. In a number of plants an operating rule has been established to the effect that scum should not be pumped alone, but should always be mixed with sludge, and that any pumping period should be ended with an appreciable time of pumping sludge alone in order that a minimum amount of scum will be left in the line to congeal. This practice has been found to be helpful.

At Buffalo a 10-inch cast iron discharge line for raw primary sludge some 600 ft. long was found to fill with grease in a period of a few months. Cleaning was accomplished with live steam introduced through an injector at the pump end of the line. The injector was made to mix water and steam and produced a flow of hot water through the sludge pipe. The grease accumulation would begin to break away from the walls of the pipe at a temperature of approximately 150 deg. F., and the pipe was found to be well cleaned at a temperature of approximately 180 deg. F. Cleaning with steam has become routine, being done approximately every four months.

The procedure is accompanied by some difficulties. In the first application of steam a section of the cast iron pipe was cracked by too rapid rise in temperature. With cast iron pipe it is necessary to both heat and cool the pipe slowly to avoid breakage. Another problem with bell and spigot pipe is the tendency for the joints to open and leak as a result of the contraction and expansion.

At some other plants, grease in sludge lines has been removed by pressure. The use of high pressure pumps at New York City plants has been mentioned. Sometimes water under high pressure has been used. It is reported that in some cases grease and other accumulated solids have been forced out of pipes in long continuous "slugs" by the application of pressure.

While these two methods, and probably others, have been effective in cleaning sludge lines, it is still advisable to make the line accessible. Outside the pump rooms the pipe may well be placed in tunnels. If this is not possible, manholes may be built around the bends, and cleanouts provided at bends and at other points for rodding and other cleaning methods, to be used if necessary.

It is suggested that, in larger sewage treatment works, sludge lines be laid in duplicate and be made of steel. This will permit cleaning the lines of grease accumulations by the application of steam or hot water and, if the duplicate lines are cross connected, this cleaning operation can be done without interrupting sludge pumping.

Metering

The metering of sludge is admittedly difficult. Although far from perfect, the Venturi meter is generally found to be the most satisfactory. Accuracy cannot be expected, and refinements in the meter design therefore are not justified. It has been found that one or two openings directly to the interior of the meter are more satisfactory than a Piezometer ring, as the ring is easily plugged with solids. Special cleaning and flushing devices and connections are also helpful.

Sometimes the use of any kind of meter for sludge is questioned because of the difficulty of obtaining satisfactory operation. It is suggested, however, that a meter is worth while, not only because it gives some measure of the rate and quantity of sludge flow, but also because it can serve as a useful indicator to the pump operator. The flow of sludge through a sludge pump may be stopped at any time through clogging of a line or lodging of some obstacle in a valve, and that this condition may not be observed by the operator without some form of indicator. A sharp drop in rate shown by the meter indicates such an interruption in flow.

Likewise, an operator may start a pump without knowing whether or not the sludge actually starts to flow. A normal indication by the meter when starting a pump is reasonable assurance that sludge is flowing, while failure of the meter to respond calls for investigation of the pump or motor, or both. It is the writer's experience that a sludge pump operator gets the "feel" of the situation so that he becomes skillful in using the meter as an indicator of pump operation, and may also use the pump to indicate the meter operation. Thus if a meter shows no flow while the pump is running, an operator may clean the valves and otherwise assure himself that sludge will flow when the pump is in operation. If the meter still does not register, it is reasonable for him to conclude that the meter needs attention.

This kind of operation appears to be troublesome and a procedure which needs improvement. There are, however, many troublesome factors in handling sludge and this is just another case in which certain maintenance operations must be accepted as routine. In operating a plunger sludge pump, it is routine to clean valves, and constant attention to a sludge meter is in the same category. Flushing of meter connections may well be done daily or oftener to prevent more serious difficulties, and further cleaning of the meter may be required at frequent intervals. In this connection the flushing system for the meter should be of adequate pressure so that the excessive pressures which sometimes occur in the sludge lines will not overcome the pressure of the flushing system.

Problems in the Sludge Tank

Probably every sludge tank accumulates scum at the top. Some prefer to call it top sludge. Whatever its name, it is obvious that some of the solids introduced into a sludge tank go to the top while others settle to the bottom. Evidence of scum accumulation is found in the answers to inquiries sent to plant operators

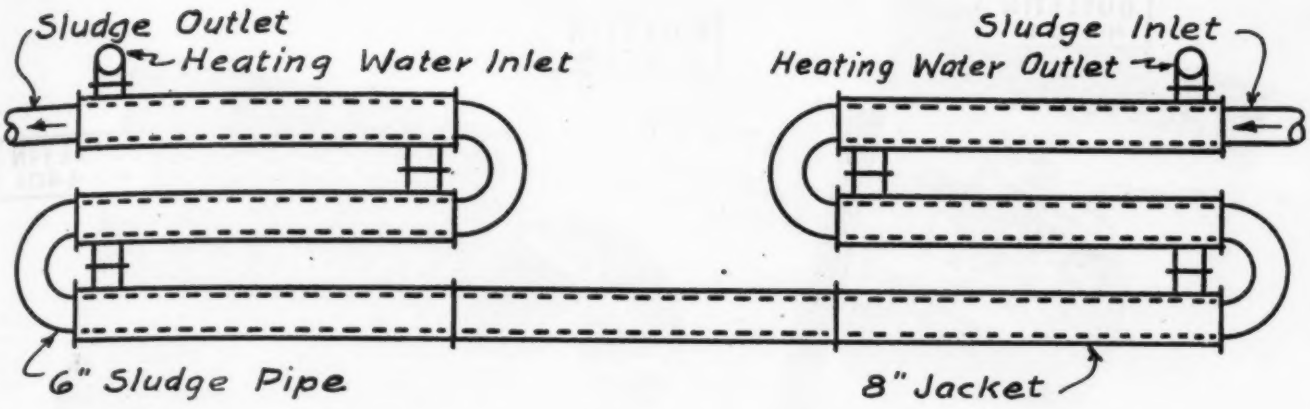

Fig. 2—Heat Exchanger for Sludge

by Wisely and reported in *Sewage Works Journal*.[1] Considerable progress has been made in designing tanks and equipment and in providing means for reducing the quantity of top sludge and for minimizing the difficulties resulting from its accumulation. It appears reasonable to assume, however, that where there is sludge there will be scum or floating solids, and that this should be recognized in the design and the operation of sewage treatment works.

The characteristics of the top sludge vary with the nature of the raw sludge and the conditions under which the sludge tank operates. They have a marked bearing on what can be done and what should be done to control or reduce the quantity. In sludge tanks of large capacity the digestion of the top sludge may keep pace with its accumulation and no problems occur, while with tanks of more limited capacity the floating material sometimes builds up to a thickness of several feet. If the solids content increases to above 20 per cent, the material will not flow in a pipe and is therefore difficult to move. It tends to become inactive and may seriously encroach on the digestion capacity of the sludge tank.

In the design of sludge tanks it appears wise to consider the possibility of top sludge accumulating to an extent which may cause trouble. Structures and equipment which keep the sludge moist have merit, and circulation is helpful. Some means for increasing moisture content and withdrawing the material may be appreciated by an operator who finds his sludge tanks handicapped with a thick layer of dense top sludge.

One arrangement for withdrawing this material which has been found effective is a pipe line carried to a point near the top and center of the tank and connected to the suction of plunger pumps. A vertical drop of some 20 feet in this pipe from the inlet point near the top of the tank to the level of the pump provides a "reservoir" into which the scum can flow as it is softened and from which the pump can draw the material. A spray in the gas dome and over the open end of this vertical pipe softens the scum until it will flow. It has been found that scum as high as 40 per cent solids can be moved with this arrangement, and that even the densest scum will gradually flow to the center of the top of the tank as the material is removed.

To attempt to make specific suggestion for operators on methods for solving scum problems is of questionable value, because no two situations are alike. Some ingenuity is required at each plant and operators have shown a high degree of skill in solving their own problems. However, a brief summary of ideas may be helpful.

Obviously, sufficient observations should be made to determine whether solids are accumulating to such a depth as to be troublesome. If that appears to be the case, measures may be applied to promote the digestion of the material. These may include increasing moisture content, circulation or stirring, and the addition of chemicals for pH control or to otherwise promote digestion.

When the situation is not brought under control by these measures, it may be advisable to remove some or all of the scum. It must be admitted that removal is not a final answer, as disposal after removal may be no small problem. Where incineration is provided, the material may be filtered and burned, with care being taken to control temperature in the furnaces. Drying on sand beds and disposal as fill is another possible method of disposal. Some effort in keeping the scum under control is worth while, as the emptying of a sludge tank is a major operation, particularly if it becomes necessary because of the accumulation of scum.

The heating of sludge tanks by hot water coils within the tanks has been common practice since the first use of separate digestion tanks. Although simple in design and operation, this method has not been entirely free of trouble. If the water is too hot, collection of solids on the outside of the coils impairs the transfer of heat. The pipes and their supports sometimes tend to retard the free flow of the sludge. Expansion and contraction of coils in large tanks requires consideration in design. Coils sometimes break and the emptying of a tank for repair of the coils becomes necessary. Mr. W. E. Gerdel reported a break in a heating coil at Cleveland in 1940,[2] and J. W. Johnson has described repairing broken coils at Buffalo in 1943.[3]

The direct application of steam has been used successfully as reported by Mr. A. M. Rawn.[4] This method is worthy of consideration where steam is available. It does not apply so well where gas is used in engines, because the waste heat from engine cooling water and exhaust is largely recovered at low temperature and must therefore be used as hot water.

The heating of sludge through some form of heat exchanger outside the sludge tank has been tried with only partial success. Heating in an open tank may produce objectionable odors. An exchanger involving passing sludge through small piping is subject to trouble from clogging. In a large plant now under design it is proposed to use an exchanger built of 6-inch sludge pipe around which will be an 8-inch hot water jacket (see Fig. 2). This will be installed in the pipe tunnel between the source of sludge and the sludge tanks. The pipe is large enough to prevent clogging, the system is enclosed and will not produce odors, can be cleaned with steam or hot water, is accessible, and its use helps to keep the sludge tank clear. Equipment for direct application of steam is to be provided for use when insufficient heat can be obtained from waste heat from engines.

Conclusion

In this discussion of problems in handling sludge, specific statements or detailed recommendations on how problems should be solved have purposely been avoided. The wide range in characteristics of sludge and the differences in conditions and requirements at various treatment plants make it difficult to draw general conclusions from experience. An effort has been made to call attention to a few experiences and to comment upon some difficulties encountered and the remedies which have been used to overcome them. Additional descriptions of experiences, particularly relating to procedures which have coped successfully with sludge handling problems, will be helpful.

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SEWAGE AND SLUDGE PUMPING

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Part I—Sewage Pumping

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multi-stage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside-packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B. T. U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,653,200 foot-pounds = 3,600,000 joules = 3420 B. T. U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B. T. U. per hour = 42.5 B. T. U. per minute = 0.71 B. T. U. per second = 2.64 pounds of water evaporated per hour at 212° F.

1 kilowatt = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B. T. U. per hour = 57 B. T. U. per minute = 0.95 B. T. U. per second = 3.54 pounds of water evaporated per hour at 212° F.

1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B. T. U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pounds of water evaporated per hour at 212° F.

1 B. T. U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pounds of water evaporated at 212° F.

1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B. T. U. = 0.0000005 horsepower-hour.

1 joule = 1 watt-second = .000000278 kilowatt-hour = 0.00095 B. T. U. = 0.74 foot-pound.

EQUIVALENTS OF OUNCES IN WATER AND MERCURY

Ounces	Inches of Water	Inches of Mercury	Ounces	Inches of Water	Inches of Mercury
.3	.521	.038	8	13.9	1.020
.576	1.0	.073	9	15.6	1.148
1	1.7	.128	10	17.4	1.275
2	3.5	.255	11	19.1	1.403
3	5.2	.383	12	20.8	1.530
4	6.9	.510	13	22.6	1.658
5	8.7	.638	14	24.3	1.785
6	10.4	.765	15	26.3	1.913
7	12.2	.893	16	27.8	2.036

MAINTENANCE OF SEWAGE PUMPING STATIONS

By A. L. SODEN
Chief Operator
Sewage Treatment Works, Trenton, N. J.

THE writer, after some fifteen years of experience with seven pumping stations containing twenty-seven pumps with capacities from 50,000 to 11,000,000 gallons per day, has come to the very definite conclusion that maintenance of this type of equipment involves three main objectives, proper lubrication, cleanliness, and frequent detailed inspection. At first thought the first two involve the last, but dumping oil or grease into a machine plus wiping it off do not constitute inspection any more than feeding and bathing a baby is a substitute for a doctor's periodic checkup. The point I wish to drive home is that good maintenance catches trouble *before it starts* and postpones indefinitely the day when the machine must be scrapped for any other reason than obsolescence.

The use of good oil and grease is a very essential item. Lubricants not suited for each particular piece of equipment may, however, no matter what they cost, do more damage than a cheap oil of a suitable character. It must be kept in mind that too much oil in many cases tends to cause more wear than too little, due to the fact that dust, always present in the air, will mix with the oil and act as an abrasive when passing through the bearings. This situation is more serious in a gravity or pressure feed system than with the oil reservoir type.

It is axiomatic that efficient lubrication is a matter of using good lubricants, properly selected, in the correct quantity, at the right intervals. Neglect or omission of any of these factors means accelerated depreciation and breakdown.

Low Price—High Cost Lubricants

Cheap lubricants are costly in the long run and if the average operator would only sit down and figure the total saving per year in a few cents less per quart of oil, or pound of grease, as against many dollars for new bearings, sleeves and shafting, damaged by cheap "bargain" goods he would realize that the best is none too good. We had an example of this in Trenton where for a time the purchasing department paid twenty-seven cents per gallon for automobile oil which was bought on a price basis.

Even though good materials are supplied, one must be certain that they are of the right weight, viscosity, etc., for the job and the only way to be certain is to follow the manufacturer's recommendation for the unit being serviced, or, if this is not available, call in a lubrication engineer from one of the big companies. You will note the word "engineer"—beware of smooth talking salesmen with trick oils that never wear out, made by some magical process and sold at high prices under a fancy name.

It may seem proper to the average person that as long as the correct amount of oil or grease is in a bearing and no noise or heat is noticeable that the machine could run indefinitely. This, however, is *not* true as many pieces of equipment are installed in damp wells where condensation is present, the worst enemy of any bearing no matter what type lubrication is used.

Gravity or pressure feed lubrication systems with an oil filter in the line do not require as much attention as equipment having the oil reservoir. A good method to follow is draining and flushing these types of bearings and refilling with new oil at least every six months, and in some instances where water is present, every three months.

Shaft Bearings

Many line shaft bearings are made for grease lubrication and can be run with safety on equipment in small booster stations for about a year before flushing and repacking with new grease. We have found through past experience that it is sound economy to remove the bearings from the shafts and wash thoroughly in gasoline or kerosene, both the bearings and the oil reservoirs, thus removing all traces of moisture, old grease and foreign matter at least once a year. This procedure should be more frequent in a plant where the equipment is running continuously. Care should be taken to put the right amount of grease in a bearing as too much causes bearings to heat through increased friction.

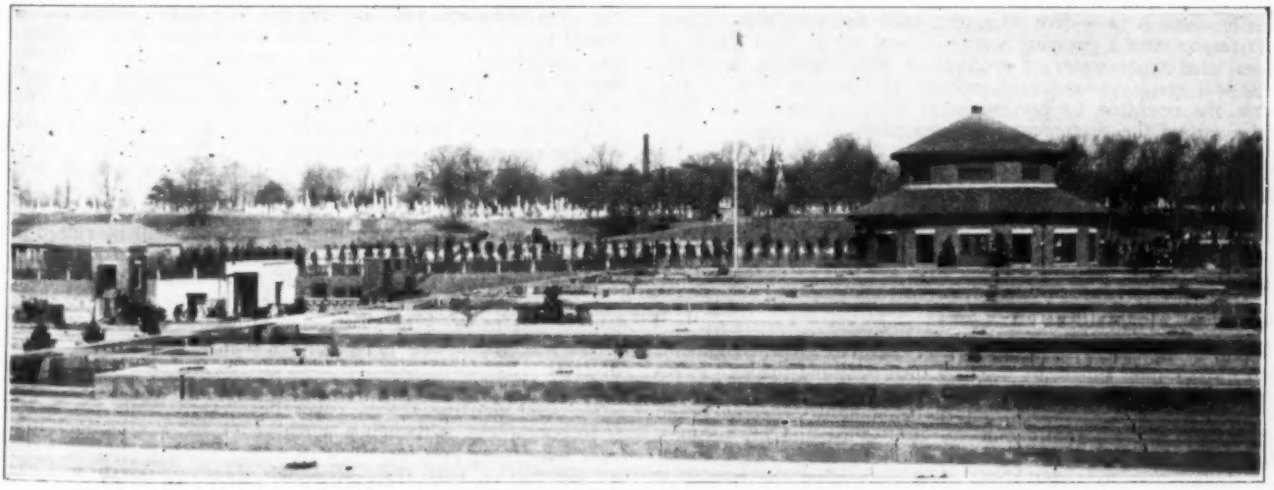
An oil filter, if used, should have at least twice the capacity of the lubricating system. This unit is used to separate the water and oil in a primary chamber and, in a secondary compartment, dirt in the oil which has a tendency to collect in bearing boxes, and any scaling which may develop in the oil lines. Such is particularly true if the latter are constructed of iron or steel pipe and fittings. Copper tubing or brass pipe and fittings are the only materials which should be used, thus preventing damage to bearings due to the stoppage of the oil grooves by pieces of rust or scale which come from iron or steel pipe, even though these be galvanized.

The matter of cleanliness around any machinery is a very important factor not only for looks but for the good of the equipment. It must be kept in mind that next to water, dust and dirt are the most destructive enemies to motors, bearings, controllers, starting switches, and many other pieces of electrical equipment that are found in a pumping station.

Motor Care

Motors must be kept free from water, oil and dirt. A good method of cleaning the interior is with compressed air or a bellows. When using compressed air care must be taken to be certain there is no moisture in the storage tank that could escape through the nozzle used for cleaning. Cleaning motors with compressed air should never be done by an amateur. The older the motor the more brittle the insulation and high pressure air through too small a nozzle can be very destructive to the motor insulation.

An excellent plan is to give the motors a thorough cleaning once every six months and at least once every two years give the windings a coat of a good grade of insulating varnish. At this time the bearings should be thoroughly cleaned and refilled with new oil, or repacked with new grease.



The Treatment Works of Trenton

One Battery of Imhoff Tanks and Pumping Station

Shop and Tool Room of the Main Pumping Station—Trenton, N. J.

Contactors

Contactors often give an operator more or less trouble due to particles of dust becoming imbedded in the contact fingers. It is a good plan never to use any lubricant on the main contact tips which are mostly constructed of copper, as oil or grease has a tendency to shorten the life of these items. If they should become pitted or burned, which in many cases cannot be avoided, remove the contact tips and clean up with a smooth file or very fine sand paper. Care should be taken when attempting to clean contacts in place not to bend or misalign the parts.

If the operating force is large enough it is a good policy to assign different parts of the equipment and pumping station to the shift operator or oilers and set up a system whereby the entire equipment and pumping station is cleaned at least once every month from top to bottom, besides the daily routine sweeping, mopping and dusting.

Insurance in Cleanliness

This, however, does not mean that the equipment should be dismantled and reassembled but it is important to get the dust and dirt, which is on the surface, before it has a chance to penetrate to the vital parts of the machinery. It will not work a hardship on any member of the operating force to do a little cleaning now and then, no matter what the title of the job he holds. By doing this a man gets around and has a chance to inspect parts of the equipment which he otherwise would not give a second glance unless trouble should develop in that particular spot.

To be clean is to be free from dirt, odor and keep tidy. There is no reason why a pumping station should not be kept clean, no matter what type—water or sewage. A little attention to cleanliness will result in continued satisfactory operating results and enable the operator to get the most efficient results and best service out of the equipment for many years.

Thoroughness

Maintenance of any piece of equipment should be as thorough as a doctor's examination, not just the usual haphazard method of looking or just glancing in the direction of the machinery. A system of inspection should be drawn up and followed to the letter.

Commutators and Brushes

Detailed inspection of motors, shafting, electrical equipment, pumps and piping should be done by men qualified through years of experience for they know what to look for in each unit.

In the case of single phase motors, commutators become rough and burned through continuous operation, dust and oil accumulating being the chief cause. Commutators should be polished with sand paper on a flat block of wood so that the insulation between the segments will be cut back even with the copper. Under no circumstances use emery cloth or emery paper in this operation. A commutator hone with the correct radius is the most efficient tool to use for this purpose.

The brushes should move freely in the brush holders, with the proper spring tension as recommended by the manufacturer. If they do not move freely, a good contact with the commutator will not be made during the starting period. Both brushes and brush holders should be inspected periodically to see that the brushes have not worn down to a point where they are so short that the brush holder springs cannot press the brushes against the commutator, thus causing burning of the brushes and commutator through arcing.

Motor-cleaning

It is a good policy in the case of single phase motors, having a short-circuiting device, to overhaul once every year. Motors of this type are hard to clean if not dismantled and every part thoroughly washed. There should never be any trouble at this point except for an abnormal accumulation of dirt or frequent overloads in excess of the maximum capacity of the motor.

The normal running temperature of an electric motor is considered a few degrees above the room temperature and should never be allowed to exceed the general standard of forty degrees centigrade above surrounding atmosphere. Motors will carry a full load continuously with no cause for concern if the room is well ventilated. Overloads or undue friction in the bearings will cause the temperature to rise and should be investigated immediately to remedy the trouble.

Motors of different sizes have their own peculiar sound when running, so an operator after a time will become accustomed to this sound and should any noise not characteristic to the motor develop, he will immediately detect it and look for the trouble and remedy it before any damage has been done.

Shafting and Bearings

Shafting in any plant requires attention more often than other parts of the equipment, to insure the longest possible life of the shaft and the shaft bearings. Shaft alignment may be as true as it is humanly possible to make it, but it will not necessarily stay aligned. A bearing wearing due to friction may cause a slight whip in the shaft and be transmitted to the other shaft bearings, thereby causing added play from vibration. A periodic check of the shaft alignment is most advisable.

Bearings on any shafting should be painted a light color, so when a bearing gathers too much heat the paint will discolor and can be detected immediately Many plants have a thermal overload device which stops the unit when too much heat develops in any shaft bearing. The operator must go to the bearing indicaated on the panel and reset the overload switch before the machine can be started again.

In plants which do not have such a device to depend on an operator must go to each bearing and rely on his sense of feeling, even this method will not tell the true story. A thermometer should be used in any and all cases where there is a suspicion of too much heat. Generally after a bearing has carried excessive heat it is too late even for a thermometer, instead a new bearing is indicated, this being true where periodic inspection is deficient.

When a shaft bearing becomes worn, no matter how little it is false economy to leave it in service. Worn shafting will vibrate and promote undue wear on both motor and pump bearings where direct connected. A bearing in this instance would be cheaper to replace than try to get by with, as possibly a whole section of shaft or motor and pump bearings will be ruined in a short time.

In stations that are automatically controlled by float or pressure switches and no attendant is on duty any length of time, it is advisable to paint the shafting to protect it against rusting. No metal will gather rust more quickly than a highly polished piece of steel. By doing this the unit can be wiped off and be kept clean.

Polished shafting should never be cleaned while the machine is in operation. Although a much better job can be done it is a very dangerous practice. Use of emery cloth should be avoided as the residue may enter the shaft bearing boxes and cause trouble. A good cleaning with soap and water and polishing with metal cleaner will give the best results and not endanger the man doing the cleaning.

It is very important to have uninterrupted operation in many

plants, where no standby units are installed. In case of power failure sufficient emergency lights should be available and special jumpers made up for continuous operation in case of burned out starters, float switches, etc.

Emergency Wiring

Rubber covered elevator cable is the most desirable material for emergency wiring, using copper lugs at either end of each wire. This will simplify connecting to the motor and main or branch switches, thereby removing from service the broken starter or float switch. Manual control will be necessary in the case where the float switch is not working. The size of the wire used for jumpers depends upon the size of the motor. This, however can only be applied to small low voltage motors of the "across the line" type. In case of large motors such as 50 HP, 2,300 volt, consult an electrical engineer for advice.

Pump Care

Necessary tools and equipment should be on hand in case of pump failure due to clogged impellers or any overload which would cause fuses to burn out or overload switches to kick out. Any pump being overloaded can be detected by the sudden rise of the ammeter.

Wearing rings in the pump case and on the impeller should be checked occasionally for clearance by using a thickness gauge. Install new rings when the gap has become large enough to impair the efficiency of the pump. New rings installed will improve the pumping capacity, thereby effecting a saving in the electric power consumption.

Packing Pointers

A most important factor, one which can cause much annoyance to the operator and plenty of damage to a pump is the proper size and grade of packing. For pumps handling dirty water—sand and grit—a packing should be selected with some thirty-five per cent lubrication, thus saving the sleeves from being worn too quickly and excessive seepage at the stuffing boxes. No gland should ever be pulled down with a wrench except at such times as to effect the proper seating when new packing is installed. Stuffing box gland nuts should never be more than finger tight, as too tight a packing will cause a braking effect on the pump shaft thereby overloading the motor.

Care should be taken when repacking any piece of machinery to see that the strands do not twist while being forced to the bottom of the stuffing box. Never under any circumstance use more packing in a stuffing box than is absolutely necessary to keep the pump from leaking at this point.

Consult a packing engineer if in doubt as to what grade of packing the unit may require. Experimenting with packing in a pump sometimes is very costly.

The piping in most instances will require little or no attention other than caulking a few leaks that may develop, or removing clogging material which can readily be detected by the use of an ordinary steam pressure gauge. A sudden rise of the gauge when connected to the force main will indicate clogging. It is of course necessary to know the normal reading for comparison.

Check Valves

Check valves should be inspected at least once every six months, including internal parts. At this time the seats, clapper faces, and whole interior can be thoroughly cleaned. At more frequent intervals test valves for tightness. Manila paper should be used for the cover gasket after being well oiled with machine oil before installing.

The building housing the equipment must be maintained as well as the machinery. The roof must be kept in constant repair so there is no possibility of water leaking through on the electrical apparatus thereby causing untold damage. Floors should be painted and rubber matting placed thereon at points in front and rear of the switchboard to protect the operator and on the floor where traffic is the heaviest, for appearance. Walls in the dry well should be inspected and repaired when necessary to prevent any seepage of sewage or ground water.

All wood work in the entire building should be painted or varnished at least every two years to protect against dampness, also to keep the appearance of the station up to par. Costly repairs may be caused by neglecting any part of the building.

Tools

It must be understood that no person can do repair work without the proper tools. A suggested list of tools to be included along with those supplied by the pump manufacturer are:

Tool List

Socket Wrench Set (sizes 7/16" to 1⅛" inclusive).
Pliers—2 pair (1—slip joint; 1—side cutting).
Screw Drivers—set of 3 (3, 4 and 6 in. blades).
Stillson Wrenches—two (one 10" and one 18").
Hammer (machinist's, 2 pound).
Oil Cans—3 or 4 (spout oilers, plainly marked as to contents).
Putty Knife (for scraping old gaskets from pump casings).
Thickness Gauge (for spacing and setting couplings and checking clearances of pump rings).
Packing Tools—full set for removing and replacing packings in stuffing boxes).
Assorted Packings (of pump mfgr's recommendation).
Spirit Level (machinist's level of dependable make).
Fuse Puller.
Voltage Tester.

Too many so-called mechanics of the Stillson wrench type do more damage to machinery attempting an overhaul job than several years of wear and tear, to which the machine is subject. A plant of any size should have among the personnel, men capable of doing all minor and most major repairs, thereby effecting a substantial saving in a year's time over hiring outside mechanics or specialty men to come in and make these repairs.

Spare Parts

Adequate spare parts should be kept on hand at all times to replace worn out or broken parts of the equipment, thus saving time. In many cases a unit may be out of service several days waiting for some part whose initial cost may be less than $5.00. Of course, it would be practically impossible to keep enough spare parts on hand to cover the entire equipment. However, essential parts: such as holding coils for contactors likely to burn out any time, and such parts that have to be made up special at the factory, taking 10 to 30 days for delivery, should be stocked.

A most important item in the operation of a plant is the budget. No matter how well the equipment is maintained, normal wear and depreciation must be taken care of. It is false economy to repair only one part of the machine and not replace all the worn parts, just to save a few dollars temporarily.

The old cry is heard many times about effecting economy by using drastic and scientific measures which look very good on paper but in general practice are not worth a second thought, compared to the cost that is likely to be involved by delaying necessary repairs.

Value of Record Keeping

Keeping records of plant operation is an important factor. Although at the time of recording the data compiled may not seem to be of any significance, it later can be used as a reference for comparing the upkeep, electrical energy required by the different units and depreciation. An excellent method to follow is the frequent reading at stated intervals of all instruments and gauges on the units that are operating, making notations from time to time of any adjustments together with the routine work as required of an operator while on duty. Daily tabulation of all charts and logs will readily tell the story of how the plant is operating—normally or otherwise. At the end of each month the daily tabulations can be set up in the form of a monthly report, showing for example, amount of rainfall, daily pumping average, daily maximum and minimum flow, amount of screenings and grit removed, and amount of sludge removed from different tanks.

The above data can easily be transformed into a yearly report going into more detail if necessary to show the cost of pumping and treating the sewage.

In conclusion, an operator without the aid of expensive testing instruments can readily operate a plant by using some degree of intelligence and the better known common sense. His natal equipment of eyes, ears, nose and sense of touch are all invaluable aids provided, of course, that his head is something better than a hatrack.

AIR RELEASE FOR SEWAGE PUMPS

Solves Pumping Problem

By W. W. GLOVER
Chief Engr., Simplex Valve & Meter Co., Philadelphia, Pa.

THE continuous and satisfactory service of sewage pumping units is very frequently affected by alternating pressure and vacuum conditions, due to automatic pump starting and stopping. This condition poses the problem of maintaining at all times the priming of the pumps. A particular case in point is that of the low-lift sewage pumping station at Pottstown, Pa.

At the Pottstown plant there are two pumps that deliver sewage from the low-level system, comprising approximately one-half of the sewerage system of the town, to the junction manhole approximately 1,000 ft. distant. From that point the total flow enters the treatment plant. The pumps deliver against a head of approximately 45 ft., taking suction from a common wet well in which float switches effect automatic operation. At the present time one pump has capacity sufficient for normal requirements so that the other is idle. One unit is operated for a 12-hour period during the day, while the other unit is operated the remaining 12 hours handling night flows for one week. The cycle is then alternated for the next week so that the two pump units have, in the long run, the same amount of service and the same types of flow to handle. When in service the pumping cycle provides an operating time of 12 to 15 minutes and an idle time of 6 to 8 minutes, except during the low flow hours of 12 midnight to 5 a.m., when the idle time is approximately 45 minutes.

The center line of the pump casing is at elevation 15.

The float switches are so set as to start the pump when the suction well level is at elevation 17 and stop it when the level has dropped to elevation 13. Once each day the wet well is drawn down to elevation 10.5 in order to clear it of the accumulating heavier solids. For general diagrammatic view see Fig. 1.

The Problem and Attempted Correction

Under the circumstances a vacuum is present in the pump casing a considerable portion of the time, tending to release air from the sewage or draw it in at glands and joints. Air or gas is also liberated in some amount during normal operation. It is, therefore, necessary to displace accumulating air from the pump during operation and to prevent the entrance of air during periods of shut-down and low wet well level. Such prevention was attempted by placing an automatic air release valve on each pump casing near its outlet, just ahead of the check valve (Fig. 1). Sewage with its varied makeup always presents problems to mechanical equipment, but this case was further complicated by the fact that usually there is a certain amount of grease and oil present and frequently there are large quantities of it.

The original valves were not able to cope with this condition and the result was a need for dismantling and cleaning them two or three times a day. It was also necessary to have a manual release valve for those times when the pumps had to go into service at once without permitting out-of-service time for cleaning. This was a serious problem, especially since the pumps are three floors below the operating level and the station is 1,200 ft. from the main part of the treatment plant. It took much valuable time of the operating personnel to do all of this.

Problem Solved

The problem was presented to the writer's company and it was recommended that a Model B Simplex sewage air release valve be installed in these locations. The valves were located in the same place (Figs. 1 and 2) as the original valves and serve under the same operating conditions. These air release valves have now been in service for several months and are giving entire satisfaction. Not once in this period have the pumps lost their prime. On one occasion during this time a float switch failed to function and the wet well was drawn down to the bottom of the suction pipe and held there approximately for three-quarters of an hour. This brought a large quantity of floating grease through the pump and unusual quantities of air. This all was handled, however, without affecting the pumping efficiency thereafter.

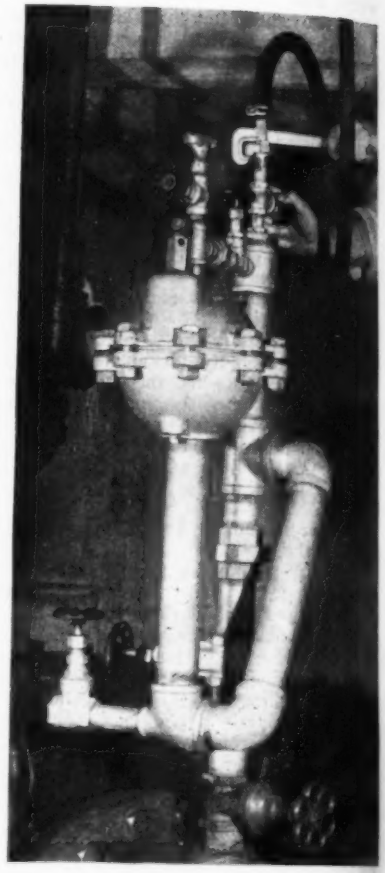


Fig. 2 — Sewage Air Release Valve Being Back Flushed

Maintenance consists of flushing with clear water using the disconnector fitting shown in Fig. 2. Any sediment that carries over has an opportunity to settle and be flushed out at a lower blow-off valve. Air is automatically vented whenever the pump casing is under pressure, and a vacuum seal at the valve outlet prevents air from being drawn back into the valve or casing during shut-down periods.

With this arrangement in service, maintenance has been reduced to one operation per week resulting in a time saving of approximately 10 hours each week. This is an important consideration at any time, but especially now, with the great shortage in manpower. It is expected that an analysis of future pump operation will show very definite power savings because of the elimination of those occasions when the pump goes into operation with the casing largely filled with air, resulting in a useless churning of the pump without producing any sewage flow.

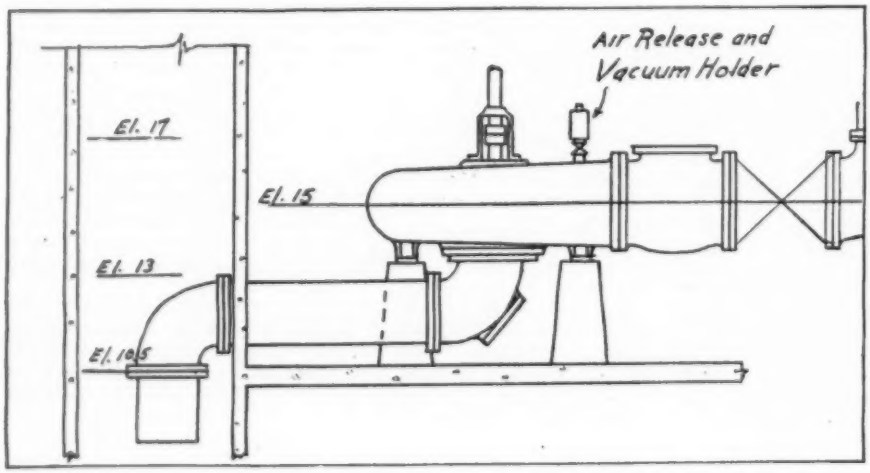


Fig. 1—Diagrammatic Sketch of Pump, Wet Well Elevations and Location of Air Release and Vacuum Holding Valve

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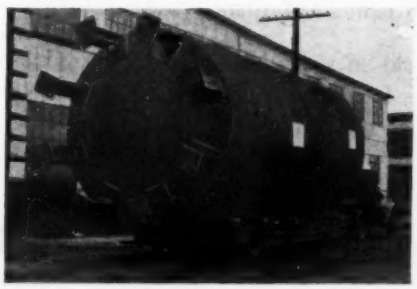
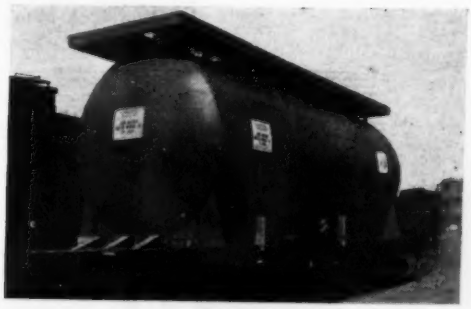
Track mounted flame cutting machine (lower photo) and modern planograph for precision cutting of steel (upper photo). These tools indicate the modern equipment in the Nooter plant.

Metal spraying equipment of latest type, restoring worn bearing area.



12'-0" x 25'-6" Steel storage tank of ASME welded construction.

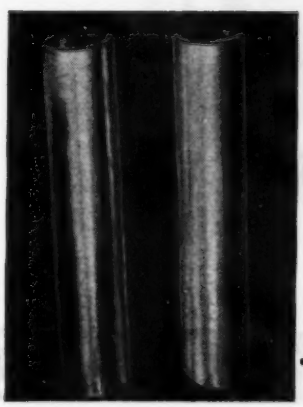


Steel storage tank protected on interior with metal sprayed zinc.

Cast iron pump plungers restored to size with sprayed stainless steel.

Lining interior of storage tank with zinc by metal spraying.

Large chemical mixing tank of stainless steel.



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170 Pringle St., Kingston, Pa.

Manufacturers of the

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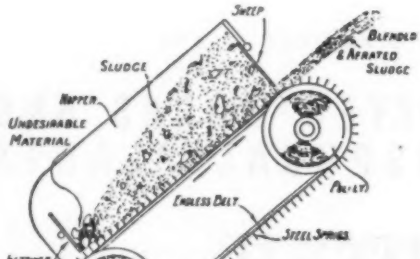
At hundreds of sewage disposal plants the Royer is converting sludge as it comes from the drying beds into an effective, ready-to-use fertilizer. It has also converted the cost of incinerating or burying sludge into a steady and substantial revenue for this ever-growing list of sewage works.

The still-growing demands in many quarters of the globe for more food from America make it imperative that every source of fertilizer be utilized to the utmost. The fertilizing values in sewage sludge have long been known. More recent experience has disclosed that sludge has the ability to retain its fertilizing value for an appreciable period; stimulating plants grown throughout the growing season. Too, the fertilizing elements

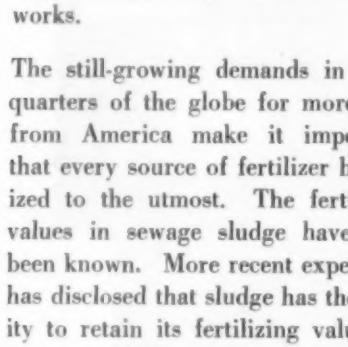


in sewage sludge are not leached out under heavy rains. The nitrogen fixation bacteria in sludge are powerfully conducive to soil fertility, and also have the power to transform the nitrogen in the air into useful compounds which plants assimilate.

The sludge cake in your drying beds has all these fertilizing values; but not in usable form. But it can be made so—with the Royer—at no greater cost than is required for burning or burial.

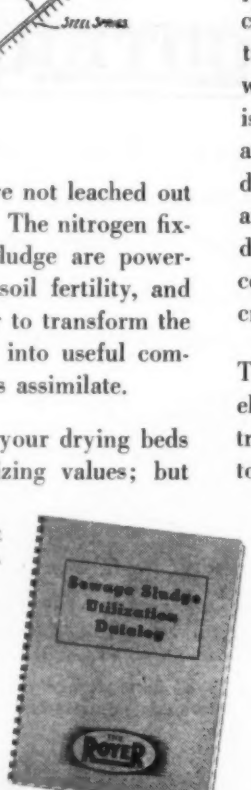
Sludge cake is shoveled into the hopper of this rugged, inexpensive machine, the operation of which is pictured at left. On the endless belt with its rows of steel teeth, the sludge is thoroughly shredded, mixed, aerated, reduced to pea size, and further dried. Refuse is automatically separated and discharged. The Royer discharges onto pile or truck an excellent fertilizer, suitable for food crops.

Twelve stationary and portable models, with sizes for every plant: electric motor, gasoline engine and belt-to-tractor driven.

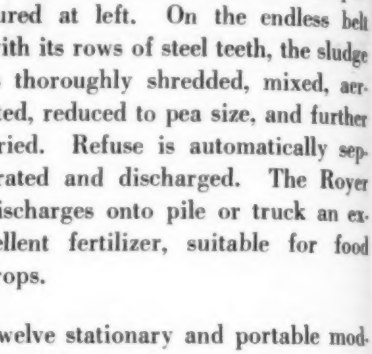


Royer "Jr." (Electric Motor)

Prepare now to convert the cost of sludge disposal into profit. Write for a copy of the "Sewage Sludge Utilization Datalog" which contains comprehensive data on the fertilizing values of sewage sludge, and how to utilize them. Complete information on the Royer, with names of typical users.

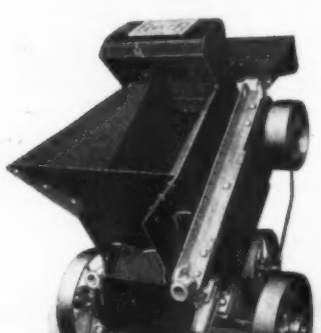


THE ROYER



Royer "Jr." (Gasoline Engine)

Model "NSD-S"



Model "NSM-2"

Model "NSH"

ROYER FOUNDRY & MACHINE CO. KINGSTON, PA.

SEWAGE SLUDGE AS A FERTILIZER*†

By A. H. NILES
Superintendent, Division of Sewage Disposal, Toledo, Ohio

NEW operators of sewage plants have often been amazed at the lush growth of garden produce which springs up as volunteer plants around sewage works, many times growing in the partially dried sludge cake undiluted with soil. This observation probably occurred most frequently with tomato plants, which as they grew were much sturdier, much deeper green and much larger than those which happened to grow in the surrounding soil unaffected by sewage sludge.

This new operator probably had only a passing interest in the appearance of these plants but as the season progressed and the fruit began to ripen, the day came when he was perhaps short of sandwiches or was long on appetite. The appearance of a particularly large and luscious looking tomato became irresistible. He had become sufficiently well acclimated to the atmosphere of a sewage treatment works to overcome his natural aversion to the thought of eating a fruit or vegetable which was fertilized directly by human feces, whether fully digested or not.

As this new operator sampled the appealing fruit, he smacked his lips and probably murmured "Hmm—not bad." From that time on he was sold, and being more or less a loquacious individual, did not wish to hide his discovery "under a bushel." He told his friends and they in turn told theirs so the story of sludge as a fertilizer began to be a matter of not uncommon knowledge. However, as in most cases of this kind, there was considerable misinformation disseminated along with the truth. Soon extravagant claims were made that sewage sludge was the universal panacea for all the ills of the agricultural world. Unscrupulous promoters claimed that sewage plants could be made self-supporting solely by the sale of their sludge as fertilizer.

Farmers long had believed that the only difference between the commercial fertilizer manufacturer and Jesse James was that the commercial product gave no visible evidence of the company having horses, and the salesmen usually did not wear spurs. Soon the commercial fertilizer companies were worried to the point where they were putting out their own brand of propaganda. These statements were that sewage sludge was of such low value that it was not worth hauling home or spreading on the fields even if given to them. Also, that it was full of disease producing bacteria and the user of the produce would certainly contract horrible afflictions or death. As is almost universally the case, the truth, probably, lay somewhere between these two widely divergent viewpoints.

Early Work at Toledo

The writer, being of Welsh extraction, which according to some, is a Scotchman raised to the *n*th power, felt that it was economically wrong to throw away anything of demonstrated value. When the Toledo sewage treatment plant was started, it was decided to give the sludge away for a limited time for advertising purposes. This was all right except for the fact that a few persons obtained sludge which was insufficiently dried. When this was spread upon their lawns and their small children ran across the yard and tracked the sticky mess into the house, their irate mothers promptly consigned the sludge and all persons connected therewith to the place where sludge drying could be most economically accomplished. These unfortunate incidents, together with the psychological fact that, to many persons, anything obtained "for free" has no value, gave the sewage sludge program something of a setback before it really got under way.

A start was made, however, with an attrition mill borrowed from a miller friend. It was not well suited for the purpose but did a passably good job. This was followed by a threshing machine concave and that in turn by a light farm hammer mill primarily suited for grinding grain and feed. Quite a lot of tonnage was put through that old farm mill and the product packaged in used calcium chloride burlap bags obtained from the Street Division. This package was an unattractive one and, besides, its printing indicated that it contained a product to lay dust or melt ice instead of to grow plants. It was sold to the relatively few persons who had previously used the free sludge and were sufficiently pleased with the results to part with real money. This was especially noteworthy because it occurred at a time when pocketbooks were flat—when the CWA leaf-raking program was at its height and national budgets were ending with six zeros instead of nine.

Finally, in 1937, a WPA project was approved to construct a plant to prepare economically the dried sludge for fertilizer and a warehouse to store it in. A contest was initiated in June, 1938, to name the child formally. Many names submitted were not thought usable because of being too expressive, but as a final result, the infant was christened "Tol-e-Gro." Its godfather was rewarded by a handsome prize of 10 bags of the material—a part of which he promptly gave away to his close friends and neighbors.

A multiwall paper bag, printed in two colors, with analyses and complete instructions for use was adopted together with modern equipment for preparing, bagging and handiing. A modest newspaper advertising program was inaugurated and a salesman hired for two seasons to get the merchandising campaign under way. Most of this took place in 1938 and 1939. Since that time the only advertising done has been the printing of folders used by dealers to acquaint their customers with Tol-e-Gro. No salesman has been needed since 1939, for every bit of Tol-e-Gro that could be dried has been sold. In the spring of 1943 at least 250 tons more could have been sold if it had been available.

Just about this time, in the Fall of 1937, the Toledo plant had the good fortune to obtain a chemist who had the background, the training, the energy and the inquisitive mind to do a good job of research. His assignment was to find out what made sewage sludge "tick." It is the purpose of this paper to tell you some of the things he found out.

Fertility Factors in Sludge

First of all, from general observation, it was assumed that sewage sludge had something that promoted growth other than the amounts of nitrogen, phosphoric acid and potash that could be determined from analyses in the chemical laboratory. All that is necessary to confirm this observation is to read the history of China. The Chinese have used their waste products—human, animal and vegetable—for centuries as fertilizers. Their lands are still among the most fertile in the world. Chemical fertilizers were unknown to these uninformed people, yet they maintained the fertility of their land. Their country was too crowded to move to more fertile, virgin fields. It was absolutely essential that they maintain their soil fertility. To do so they used the above mentioned wastes, putting them back into the soil. In Europe, the farmers of today will not tolerate the waste of manures—even human manure is carefully used for fertilizer. These farmers, undoubtedly, knew very little and cared less about how much nitrogen, phosphoric acid and potash were in their wastes. However, they did know that these wastes were what their ground needed to keep it fertile and productive. These manures and natural wastes actually were poor fertilizers if compared analytically with some of the so-called complete fertilizers, such as 4-12-4 or 5-10-10, etc.

It is true that these chemical fertilizers are giving good results. But is it not reasonable to believe that these natural wastes must have something in them or their action which makes them better fertilizers than the straight analysis of nitrogen, phosphoric acid and potash would indicate? No one can make up a standard mix commercial fertilizer with the same analysis as Tol-e-Gro, which is 2.0-2.0-0.30, and come anywhere near to obtaining the results that can be obtained by using Tol-e-Gro or a barnyard manure with a similar analysis. Immediately, it will be said that the organic form of nitrogen is of longer duration and the plant fed more continuously, but that again is not the whole story. The purely chemical analyses in the laboratory do not show the countless billions of little nitrogen fixation factories found in sewage sludge and manures which take nitrogen from the air and convert it to the form of nitrogenous compounds easily assimilable by the plant life. Tol-e-Gro contains enormous numbers of nitrogen fixation bacteria which are found in some soils in limited quantities but not in all soils. Their presence is conducive to good fertility. These bacteria are collectively known as Azotobacters and Nitrobacters. These micro-organisms have the power of transforming the nitrogen in the air to useful compounds which can be assimilated by plants for food. They not only make nitrogen more available to plant life but they also attack and break down humus, straw, old dead roots and other organic substances in the soil, to useful, life-giving stimulating compounds used by the plant life.

*Presented at 20th Annual Conference, Michigan Sewage Works Association, East Lansing, April 5-6, 1944. Reprinted from *Sew. Wks. Jour.* 16, 720 (1944) by permission of the editor.

†Ed. Note: Although this article was prepared about and mentions Tol-e-Gro, the sludge from Toledo, Ohio, the information herein is undoubtedly applicable to digested sludge from other sewage plants.

Nitrogen and Nitrate Content

It was found that Tol-e-Gro will increase its nitrogen content by 20 per cent in 7 days if moistened and allowed to stand exposed to air. This nitrogen in the air is changed to ammonia and nitrates which are eagerly taken up by the plants and utilized in their normal metabolism. The Texas Experimental Station Bulletin No. 445 states that similar sewage sludge mixed with samples of different kinds of soils produced from 64 to 134 parts per million of nitrate nitrogen. This is more nitrate nitrogen than is produced in some higher analysis fertilizers. This variation is due largely to the variations of soils rather than to the sewage sludge itself.

Since a medium or normal nitrate soil will show 5 to 15 parts per million, according to Michigan Technical Bulletin No. 132, it is obvious that sewage sludge gives an abundant supply of nitrate nitrogen. Quoting from the above Bulletin No. 132, "The nitrogen of the soil organic matter is transformed to ammonia and then to nitrites and finally to nitrates by means of the action of soil organisms. This process is known as nitrification. In order for a soil to form nitrates naturally, it should have a supply of nitrogen in organic matter, be moist, warm and aerated and have the nitrifying organisms present. Soils low in organic matter are usually low in nitrate and nitrifying organisms. Growing plants obtain most of their nitrogen from the soil as nitrates." Nitrates are water soluble and, unless protected by organic matter, are easily washed through the soil.

Tol-e-Gro supplies an abundance of these nitrifying organisms as well as a good reserve supply of organic matter and prevents leaching of valuable nitrate salts from the soil. The amount of ammonia in the soil is dependent upon the same factors as nitrates, that is, abundance of organic matter and nitrifying organisms. Chemical salts used on soils are easily leached out by heavy rains and partly wasted as far as soil nutrition is concerned.

The use of sewage sludge or manure will, in a large measure, control this leaching as it will hold many times its volume and weight of moisture, thus keeping the dissolved nutrients in contact with roots for a much longer time than would otherwise be possible.

Most sewage sludges have a residual or reserve property of releasing food as the plant needs it. These organisms will make just a certain amount of excess ammonia or nitrate which is more than the plant needs. They cease production of these nutrients and cease their activity until the nitrate concentration falls somewhat. Then the nitrifying bacteria start making more ammonia and nitrate from the air. Thus, there is always available an ample supply of usable nitrogen.

Sewage sludges and manures are helpful in making heavy clay soils porous and workable. Sandy soils are helped by the humus present in sewage sludge and by the moisture-holding properties of the sludge. Sandy soils are almost always deficient in nitrifying bacteria and certain colloidal conditions which are essential to plant growth. Tol-e-Gro supplies the soil with microorganisms and helps correct these colloidal deficiencies.

Chemical Constituents

Many elements are essential to plant growth other than nitrogen, phosphorus and potassium. Many crops have been thoroughly analyzed to find just what elements are needed in their growth. Analyses were made of corn, wheat, sugar beets, alfalfa, tomatoes, barley, rye and cabbage, as reported in *New Agriculture*, April, 1937. The following elements were found to be present in the above crops: nitrogen, phosphorus, potassium, calcium, aluminum, arsenic, barium, beryllium, boron, bromine, chlorine, chromium, cobalt, copper, fluorine, iodine, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, rubidium, silicon, silver, sodium, strontium, sulfur, tin, titanium, vanadium and zinc. This totals 33 elements in all. Of these elements, 22 are present in corn, 26 in wheat, 20 in sugar beets, 27 in alfalfa, 22 in tomatoes, 14 in barley, 15 in rye and 22 in cabbage. Therefore it seems reasonable to assume that a good fertilizer should include more than just nitrogen, phosphate and potash. Tol-e-Gro shows the presence of 29 of these various elements.

Sewage sludge has an abundance of mineral elements, many of which are present in such forms as to be slowly and sufficiently available to plant life. Since about 30 different minerals are being constantly taken from the soil by crops, it seems reasonable that replacement of many of these elements is advisable.

A composite sample of 325 tons of Tol-e-Gro was carefully collected and analyses made of same sample. These analyses are quite complete for all common mineral and non-metallic constituents, and the results, shown in the accompanying table, are expressed in pounds per ton of Tol-e-Gro:

Chemical Constituents of Tol-e-Gro.

Constituent.	Pounds per ton	Constituent.	Pounds per ton
Aluminum	72	Lithium	Tr.
Arsenic	.2	Magnesium	22
Barium	1	Magnesia equivalent	36.5
Bismuth	12	Molybdenum	Tr.**
Boron	+*	Nickel	Tr.**
Bromine	Tr.**	Nitrogen	42.4
Calcium	94.8	Organic Matter	888
Ca as limestone	236.8	Potassium	7.0
Chlorine	+*	Phosphoric Acid	40.2
Chromium	5	Selenium	Tr.**
Cobalt	Tr.**	Silicon	146
Copper	16	Sodium	+*
Fluorine	+*	Sulfur	65.8
Iodine	Tr.**	Tin	Tr.**
Iron	76	Zinc	20
Lead	15		

*Undetermined amounts, but more than a trace.
**Spectrographic analysis confirmed these trace constituents.

It is fitting at this time to take up some of these various elements, showing in some measure just how and why they are vitally important in the metabolism and growth of plants.

Aluminum: Essential to plant growth. It is usually present in soils in sufficient quantity although it may be deficient in sandy soils. Along with the organic matter in the soil, aluminum is active in controlling the colloidal functions and water-conserving properties of the soil.

Arsenic: The following statement is taken from *New Agriculture*, April, 1937, issue: "Although formerly believed to be toxic in certain concentrations, it has proven beneficial and stimulates the growth when present in small quantities. As much as 1,000 lbs. per acre have not proven toxic in experimental work." Dr. J. E. Groves of Utah says "Arsenic stimulates bacterial action in the soil resulting in greater crop yield." He further states: "Arsenic must be applied in enormous amounts before it retards microscopic life." Experiments show that arsenic causes liberation of insoluble elements in the soil, especially phosphate.

Barium: Found in varying amounts in some plants. It is believed to prevent injury from excessive concentrations of other elements. However, there is not much known about the value of barium except that it is found in the structure of some plants, namely, corn, wheat, sugar beets, alfalfa, tomatoes and cabbage.

Boron: Much work has been done on the influence of boron on plant growth in the last 20 years. Warington (1923) and Breachley (1927), at the Rothamsted Experiment Station, believe that boron is essential to plant growth, and this belief is concurred in by Sommer and Lipman (1926), Johnson and Dove (1928) and others in this country. Collins (1927), working at the New Jersey Experimental Station, found that boron did have a stimulating effect when present in small quantities.

Calcium: One of the very essential elements. Non-legume crops will require at least 25 lbs. per acre, while legumes, alfalfa, clover, etc., will require 100 lbs. and more per acre. Most soils, it is true, have calcium in their make-up but it is not always in an easily available form. Calcium, more or less, controls the acid and alkaline balance in the soil. It has a controlling influence on the translocation of sugars and starches in the plant. It is essential to the construction of healthy cell wall of plant tissue.

Chlorine: Apparently useful to plants in small quantities. It seems to have a catalytic effect and tends to make other elements more available.

Copper: Found in many plants and it appears to be essential for sunflowers and tomatoes. Copper gives good results, especially on wet, boggy lands where most minerals have been leached out of the soil. Copper, along with manganese, has decidedly beneficial results with carrots, radishes, beets, cabbage and other garden crops.

Cobalt: In small quantities has been found to stimulate crops. It has been found to be important in tomato, wheat and corn culture (*New Agriculture*, April, 1937).

Magnesium: As essential to plants as phosphorus or potash, yet until recently experimental stations and fertilizer industries have paid little attention to the possibilities of a magnesium hunger or magnesium fertilization. Most plants will show from 5 per cent to 10 per cent magnesium oxide in their ash. Magnesium is a constituent of the chlorophyll molecule. It is absolutely necessary in the production of a healthy green color in plants. Magnesium plays an important role in the translocation of starches in the plant. It is an essential factor in the formation of vegetable fats and oils and functions as a carrier of phosphorus in plant metabolism. Bartholomew (1933) has gained evidence showing that soluble magnesium in plants increases the absorption of phosphorus. Cooper (1930) found that magnesium is desirable for resinous plants. Sewage sludge carries large amounts of easily available magnesium. Loew (1901) showed that for the best development of most common field crops the soil should have a calcium-magnesium ratio of 2 parts of calcium

to 1 of magnesium. During wet seasons magnesium is easily leached from the soil. The combination of magnesium with organic material is, therefore, highly desirable as the organic material helps prevent excessive leaching.

Iron: Very essential but most soils contain sufficient amounts for normal growth.

Manganese: A constituent of nearly all field and garden crops. It is now considered to be one of the essential elements for normal growth. McHargue (1926) of the Kentucky Experimental Station demonstrated conclusively that manganese was essential for plant growth. Manganese appears to be necessary in the normal oxidation reactions taking place in plant metabolism. Addition or incorporation of manganese in fertilizers to be used on alkaline soils or soils underlain with lime is important as the alkalinity reduces the availability of manganese. Therefore alkaline soils are apt to be deficient in available manganese. Manganese deficiency is due, largely, to the increasing scarcity of manure. Manure usually contains sufficient manganese for most soils. Sewage sludge contains an abundange of manganese, even more than manures, and is a very good carrier of manganese for fertilizer use.

Sodium: Easily leached from soils and should be replaced. Beets, mangoes, potatoes, wheat, barley and asparagus respond quickly to the presence of sodium salts in the soils. Some experimental stations are using top dressings of sodium chloride, or common salt, with remarkable increases in crops. Sodium seems to help conserve the phosphorus and potash and help the normal reactions in the plant.

Sulfur: Proved to be an essential element to plant growth in 1860. Sulfur is a constituent of many plant proteins, cereals, etc. Sulfur is a constituent of plant flavors and aromatic oils and is a constituent of mustard oil, onions, garlic and many other flavors more pleasant. Many plants require more sulfur than phosphorus (*Commercial Fertilizers,* Collins, 1934).

The annual loss of sulfur through drainage is estimated at between 20 and 50 lbs. per acre. Many plants will respond remarkably to sulfur. Alfalfa will respond to sulfur even better than nitrogenous fertilizers. Cases of alfalfa increases with sulfur-carrying fertilizers have been reported from 50 to 500 per cent. Sulfur increases root growth in most plants (Crocker, 1933). Garden crops such as cabbage, lettuce, radishes, beans, peas, etc., respond readily to sulfur.

Tol-e-Gro contains sulfur bacteria which change insoluble forms of sulfur to soluble sulfates which are available to plants. Tol-e-Gro is rich in sulfur—65 lbs. per ton.

Small amounts of zinc seem to be important to plant life as zinc is found in almost all of the common crop plants and fruits. Zinc controls mottle leaf and rosette in fruit trees.

Other Benefits

Users and experimenters of sewage sludge as fertilizer have repeatedly called attention to the fact that results obtained by using Tol-e-Gro and some similar products are far better than the nitrogen, phosphoric acid and potash analysis would indicate. The importance of other mineral constituents has been shown in a small way. Taking all these minerals into consideration, the results obtained by using Tol-e-Gro are still beyond those expected from the straight, routine, standard analysis.

This may be partially explained on the basis of increased moisture-holding capacity; the change in soil structure, allowing more air to enter and subsequently stimulating oxidation; introduction of large numbers of bacteria to aid decomposition and better balancing of the nitrification processes and flora of the soil.

It has been found in running laboratory comparative tests that the plants grown with Tol-e-Gro had two or three times the root growth of plants grown under identical conditions with commercial 4-12-4 fertilizers. Also, comparative tests with potatoes grown on good loam soil resulted in a 200 per cent increase for hills fertilized with Tol-e-Gro at the rate of 400 lbs. per acre. The root growth was noticeably greater and the potatoes were larger. A search was started to determine in some measure the cause of these fine results and increased root growth. In recent years considerable attention has been focused on the fact that certain organic compounds or chemical substances are able to increase root growth and stem elongation and to influence changes in plant growth. It was in this direction that the search was started.

It is well known that in the presence of nitrifying bacteria, such as Azotobacter Chroococcum, something was formed which induced increased root growth. As previously stated, Tol-e-Gro is virtually alive with nitrifying bacteria. It has been shown that these growth promoting substances are probably not made by the bacteria but are produced as bacteria break down the organic materials upon which they feed. Tol-e-Gro is rich in these organic substances. This explained, in part, the origin of these chemical substances, but the next thing was to demonstrate their presence and approximate the amounts present. These substances were found to be present in small quantities when expressed as pounds per ton, but this is more than sufficient when compared to the requirements for plant stimulation. These substances were identified as derivatives of indole, a complex organic chemical.

Growth Promoting Substances

Dr. Willem Rudolfs, head of research of the New Jersey Agricultural Experiment Station, Dept. of Water and Sewage, together with Messrs. Heineman and Ingols, reported in *Sewage Works Journal,* Vols. 10 and 12, on various growth-promoting substances found in sewage sludge. Their conclusions were that most growth-promoting substances found in sewage sludge were from indole and skatole in the form of indole acetic, indole propionic and indole butyric acids. Tryptophane is also formed by digesting or decomposing sludge. Carotene and ascorbic acid are present in limited quantities.

Many of these substances are soluble and tend to wash or drain out of the digesting sludge. It was found that concentrated filtrate collected from the underdrainage system of the glass-covered sludge drying beds at Toledo was far more potent in growth-promoting substances than the dried sludge. This corroborated the statement heard many times that "the best part of sludge is drained away."

Damoose at Battle Creek, as did Backmeyer at Marion, Ind., found this to be the case when they advocated using, and actually sold on an applied basis, quite large amounts of liquid digested sludge. This method of use certainly has its limitations, but, where possible to handle it economically, it produces wonderful results. For years Hommon, at Canton, O., has disposed of liquid digested sludge directly to a city-owned farm adjacent to the sewage treatment plant, with phenomenal crop yields.

In conclusion, it may be summed up that, measured by purely chemical analyses, sewage sludges do not compare very favorably with many commercial fertilizers. Sewage sludge probably never will drive commercial fertilizer companies out of business. Many of these companies do use sewage sludge as a base and fortify it with additional chemicals to gain the analysis desired. This, in part, gains for the commercial fertilizers some of the advantages sewage sludges have.

Even the worst critics of sludge, however, unwillingly perhaps, admit that it has some properties that give plants an "oomph" that a standard commercial fertilizer just does not have.

CONTENTS OF HORIZONTAL TANKS AND PIPE

Per Foot of Length, for Various Depths

Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given: Diameter of tank d and height of segment h.

To find area of segment.

when $h = 0$ to $\frac{1}{2}d$; area $= h\sqrt{1{,}766\ dh\text{-}h^2}$

when $h = \frac{1}{2}d$ to d; area $= h\sqrt{0.017d^2 + 1.7\ dh\text{-}h^2}$

1 cu. ft. = 7.4805 U. S. gal.

h = Depth of Liquid Inches	d = Diameter of Tank, Inches									
	12		18		24		30		36	
	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.	Gal.	Cu. Ft.
2	0.64	0.0860	0.80	0.1072	0.93	0.1244	1.05	0.1400	1.15	0.154
4	1.73	0.2317	2.18	0.2920	2.57	0.3440	2.90	0.3878	3.21	0.429
6	2.94	0.3927	3.85	0.5149	4.59	0.6140	5.23	0.6988	5.80	0.775
8	4.14	0.5537	5.67	0.7578	6.85	0.9152	7.85	1.049	8.75	1.17
10	5.23	0.6994	7.55	1.009	9.26	1.238	10.72	1.432	12.0	1.60
12	5.87	0.7854	9.38	1.252	11.75	1.571	13.72	1.833	15.4	2.03
14	.....	.....	11.04	1.476	14.24	1.903	16.82	2.248	19.0	2.54
16	.....	.....	12.43	1.659	16.65	2.226	19.90	2.660	22.6	3.02
18	.....	.....	13.22	1.767	18.91	2.527	23.00	3.075	26.4	3.53
20	.....	.....	.....	.....	20.93	2.797	26.00	3.476	29.6	3.95
22	.....	.....	.....	.....	22.57	3.017	28.85	3.859	33.4	4.46
24	.....	.....	.....	.....	23.50	3.141o	31.49	4.209	37.4	5.00
26	.....	.....	.....	.....	.....	.....	33.82	4.521	40.4	5.40
28	.....	.....	.....	.....	.....	.....	35.67	4.768	43.7	5.84
30	.....	.....	.....	.....	.....	.....	36.72	4.908	46.6	6.23
32	.....	.....	.....	.....	.....	.....	.....	.....	49.1	6.55
34	.....	.....	.....	.....	.....	.....	.....	.....	51.2	6.85
36	.....	.....	.....	.....	.....	.....	.....	.....	52.9	7.07

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DETERMINING SUSPENDED SOLIDS BY CENTRIFUGING

By ALICE L. MATHIS
Chemist
Phoenix Activated Sludge Plant, Phoenix, Ariz.

SO FAR as known, this method was not in use in any other sewage treatment plant laboratory at the time it was started in Phoenix. Its use was inaugurated because of a strong objection on the part of the author to the Gooch crucible, especially in the determination of such small quantities of material, where the loss of even a shred of asbestos makes an appreciable difference in the final results. Weighed filter papers were first tried as a substitute for the Gooch crucibles. They are not entirely satisfactory, however, chiefly because of the difficulty of weighing them with sufficient accuracy, especially when the temperature and moisture content of the atmosphere vary.

The problem of a satisfactory substitute for the Gooch crucible was solved, at least to the author's satisfaction, when a centrifuge was obtained. The centrifuge was originally purchased to be used for some other work, but when the possibility of its use for determining suspended solids was realized, it was soon put to work in that capacity also. Seen in one of the accompanying photographs, it is an International Clinical Centrifuge with a four place head for 50 ml. tubes.

Procedure

The procedure consists of measuring out a quantity of thoroughly mixed sewage into a 50 ml. centrifuge tube which has been washed, dried, cooled, and weighed. The sample is then centrifuged at top speed for 20 minutes. The supernatant liquid is decanted off and the residue in the tube is dried in the oven for 1 hour to constant weight, cooled in a desiccator for at least 2 hours, but not more than 5 hours, and weighed. The weight of the residue thus determined in milligrams, multiplied by twenty, equals p.p.m. suspended solids present in the sample.

Discussion

The length of time to centrifuge was determined by running tests on portions of the same sample for various time intervals. Intervals from 10 to 30 minutes showed little difference in the results, and it was decided that 15 minutes was enough for raw sewage and primary clarifier effluent samples. For samples of plant effluent it was found that 20 minutes was better, not that different amounts were thrown down, but because the residue adhered to the tube better after 20 minutes' centrifuging. Twenty minutes was then chosen as a standard centrifuge time for all the samples. The intervals of time for drying and cooling were also determined by comparing results obtained under different conditions. Results of several tests are shown in Table I.

TABLE I
EFFECT OF CENTRIFUGE TIME ON RESULTS

Date	Time Interval	Sample	By Centrifuge Wt. 50 Ml. Residue— Mg.	Ppm.	By Gooch Ppm.
4-12-40	10 min.	raw	10.2 9.9	201	201
4-12-40	15 min.	raw	11.8 9.2	210	201
4-16-40	10 min.	raw	13.3 12.8 13.5 12.3	av. 260	247
4-23-40	15 min.	raw	11.4 11.9	233	250
4-23-40	15 min.	plant effl.	3.0 3.0	60	64

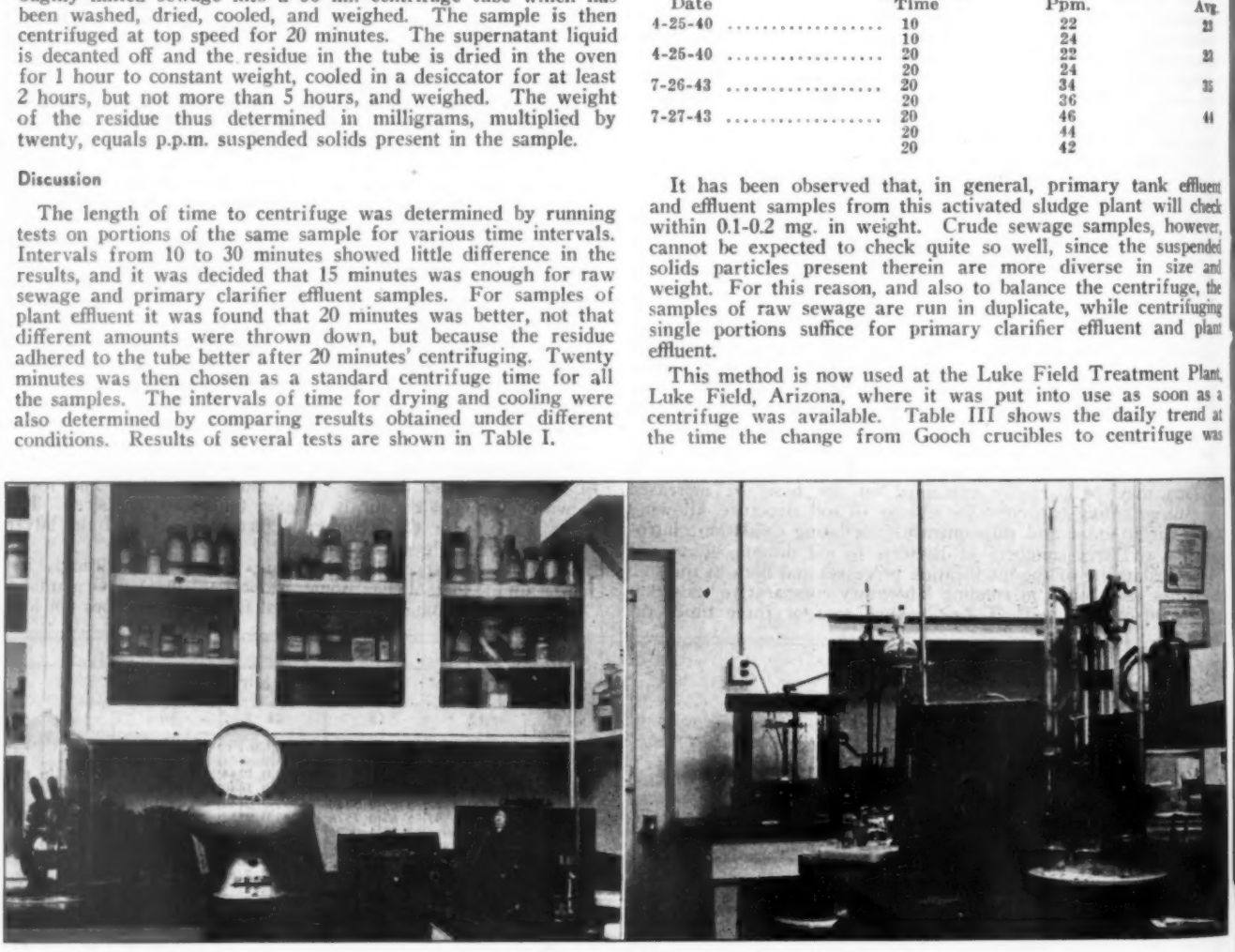
Since constancy of results is of importance in tests of this type, it is interesting to see that very close checks on samples can be obtained, as shown in Table II, listing results on the plant effluent.

TABLE II
DUPLICATE TESTS ON PLANT EFFLUENT

Date	Centrifuge Time	Ppm.	Avg.
4-25-40	10	22	23
	10	24	
4-25-40	20	22	23
	20	24	
7-26-43	20	34	35
	20	36	
7-27-43	20	46	44
	20	44	
	20	42	

It has been observed that, in general, primary tank effluent and effluent samples from this activated sludge plant will check within 0.1-0.2 mg. in weight. Crude sewage samples, however, cannot be expected to check quite so well, since the suspended solids particles present therein are more diverse in size and weight. For this reason, and also to balance the centrifuge, the samples of raw sewage are run in duplicate, while centrifuging single portions suffice for primary clarifier effluent and plant effluent.

This method is now used at the Luke Field Treatment Plant, Luke Field, Arizona, where it was put into use as soon as a centrifuge was available. Table III shows the daily trend at the time the change from Gooch crucibles to centrifuge was



Two Views of the Well-Equipped Laboratory of the Phoenix Plant
Centrifuge Used in Routine Suspended Solids Determinations Appears in Left View

made. These tests were made by Sgt. K. B. Jacobson, who learned the method in the Phoenix plant laboratory, and who is responsible for carrying out the laboratory work at the Luke Field plant. These figures were released through the courtesy of the U. S. Army Air Base at Luke Field.

TABLE III

RESULTS OF SUSPENDED SOLIDS TESTS AT LUKE FIELD, ARIZONA

1942	Raw	Primary Effl.
Oct. 7	274	94
Oct. 9	292	92
Oct. 12	334	112
Oct. 14	278	84
Oct. 16	254	74
Oct. 21	250	86
Oct. 22*	294	104
Oct. 26	254	98
Oct. 28	284	80
Oct. 30	304	80
Nov. 2	286	86
Nov. 4	328	96
Nov. 6	292	108

*Centrifuge method started Oct. 22nd.

The chief objection which might be made to this method is that there is a possibility of retention of a little supernated liquid in the tube which on drying leaves a deposit of dissolved solids, producing a higher result for suspended solids than is actual. That this is not a serious objection is shown in the results in Table II on plant effluent tests on July 26, 1943, in which the tube containing the second sample was wiped dry of any clinging drops of liquid before oven drying. If reasonable care is exercised to see that the liquid is poured off smoothly and quickly, there is little danger of losing any of the solids or of retaining sufficient of the liquid to create an error of consequence.

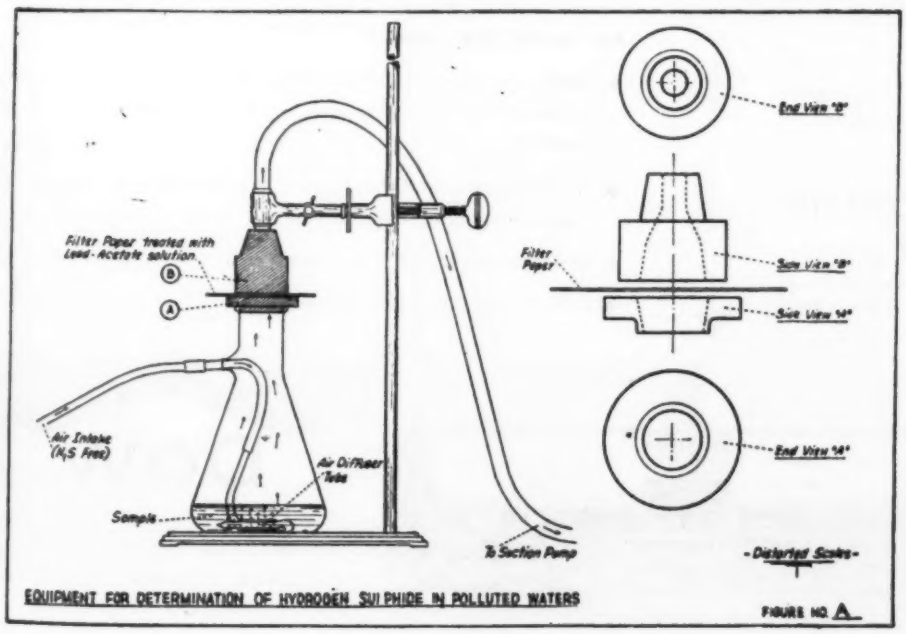
The centrifuge method is to be preferred because it is easier than the Gooch crucible method. The tubes are easier to prepare than the crucible with its asbestos mat; easier to use. There is no danger of losing any of the tube itself, again in contrast to the mat. The greater weight of the tube in relation to the surface makes them easier to weigh accurately than filter papers. The method yields consistent results, as shown by results in Table II.

DETERMINATION OF HYDROGEN SULPHIDE BY SIMPLE METHOD*

IN MAKING routine determinations of hydrogen sulphide in sewage, sewage gas, and polluted waters it was found that the procedure as described in Standard Methods was not satisfactory, due to the fact that polluted waters and sewage have an iodine demand. Therefore, a modified or special method of procedure was adopted. This special method is based upon the known fact that filter paper treated with a lead acetate solution will darken when placed in contact with hydrogen sulphide. It was found that by making a set of standards, with which any sample might be compared, consistent and fairly accurate results could be obtained.

The Apparatus

The apparatus necessary for making these determinations consists of a standard 500 ml. filtering flask, on the inside of which is placed an air diffuser made of a perforated aluminum tube connected to the flask's side tube by means of a rubber hose. On the outside of the side tube there is attached the rubber air intake hose. The lead acetate paper is held in place on the top of the suction flask between a rubber ring, "A," which is a standard Gooch crucible holder for an ordinary two-inch funnel, and a standard Gooch crucible holder, "B," as is ordinarily used with a filter flask. "A" and "B" are held together by a utility clamp fastened to a ring stand. The rubber hose which is attached to the glass tubing of "B" is connected to a suction device.



EQUIPMENT FOR DETERMINATION OF HYDROGEN SULPHIDE IN POLLUTED WATERS

FIGURE NO. A

The Procedure

In making a determination with this apparatus the sample to be tested is delivered into the flask directly from a pipette through the aeration tube. Air is then drawn through the liquid for two minutes and by so doing the hydrogen sulphide passes on up through the lead acetate paper, discoloring it. The amount of hydrogen sulphite is determined by comparing the colored lead acetate paper with the standards and converting the results into the desired units.

In order to operate this apparatus satisfactorily it is necessary that there be at least 100 ml. of liquid in the flask. Thus, if the sample being tested is high in hydrogen sulphide, it becomes necessary to dilute it with hydrogen sulphide free water. If it is desired to have the final results in ppm., this figure is arrived at by multiplying the color comparison in mg. by 1000 (mg. per liter = ppm.) and dividing by the ml. of sample used.

Example: Sample = 10 ml.

Water added to flask ahead of sample = 90 ml.

Color comparison = 0.05

$$\text{Ppm.} = \frac{0.05 \times 1000}{10} = 5 \text{ ppm.}$$

Gas may be tested by hydrogen sulphide content by passing a known volume through the above described apparatus.

Test Papers and Standards

The lead acetate paper is prepared by soaking filter paper in a 10 per cent solution of lead acetate and drying in an oven until approximately 10 to 15 per cent of the moisture remains in the paper. The paper must then be kept in an air-tight container.

Standards are made from a solution of hydrogen sulphide prepared by generating hydrogen sulphide in distilled water from iron sulphide by the addition of dilute sulfuric acid, the solution being standardized by iodine titration.

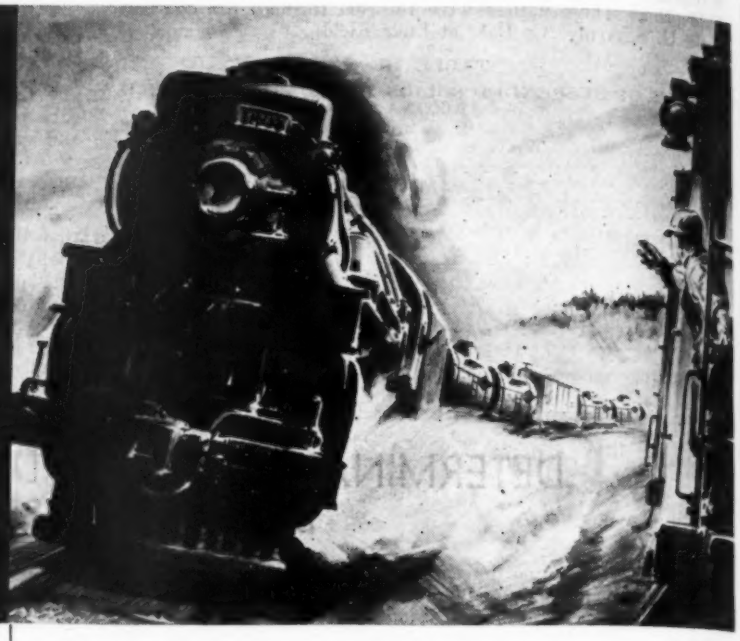
[Note: The apparatus herein described won for the author first prize in the Gadget Contest conducted by the Central States Sewage Works Association.—Ed.]

*Contributed by George Martin, Supt. of Water and Sewerage, Green Bay, Wis.

DOW CHEMICALS—ON THE MOVE TO SERVE AMERICAN INDUSTRY

Dow Ferric Chloride

60% crystals 37-47% solution



Dow Ferric Chloride 37-47% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300-lb. and 500-lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.

THE DOW CHEMICAL COMPANY

MIDLAND, MICHIGAN

New York, Boston, Philadelphia, Washington, Cleveland, Detroit, Chicago, St. Louis, Houston, San Francisco, Los Angeles, Seattle

for sludge conditioning

- minimum chemical and operating costs.
- cuts dewatering equipment cost—increases performance.
- gives higher filtration rate.

for sewage coagulation

- greater removal of suspended solids.
- lower 5-day B.O.D.
- increased flexibility to meet peak loads and low stream flows.
- economical effluent improvement.
- reduction of hydrogen sulphide odors.

for water treatment

- forms a compact, quick settling floc with complete precipitation at any pH value above 5. Retains effectiveness in cold weather.
- effectively removes large quantities of coloring matter. Precipitates tannin compounds at pH of 5 or below.
- in conjunction with lime, removes iron and manganese.
- reduces taste and odor by removing H_2S.

DOW

CHEMICALS INDISPENSABLE TO INDUSTRY AND VICTORY

ENGINEERING DATA

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc., respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" " "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8						371.60	181.02	103.62	65.69	32.00	18.32
7						266.13	129.64	74.21	47.05	22.92	13.12
6						181.02	88.18	50.48	32.00	15.59	8.92
5					316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½					243.00	88.18	42.96	24.65	15.59	7.59	4.35
4				371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½				266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3				181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½			316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2			181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½			88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼		316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1		181.02	32.00	11.61	5.66	2.05	1.00				
¾		88.18	15.59	5.66	2.05	1.00					
½		32.00	5.66	2.05	1.00						
⅜		15.59	2.76	1.00							
¼		5.66	1.00								
⅛		1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

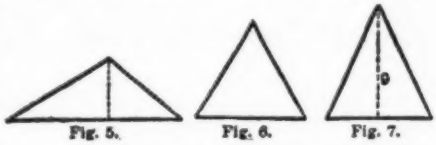


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

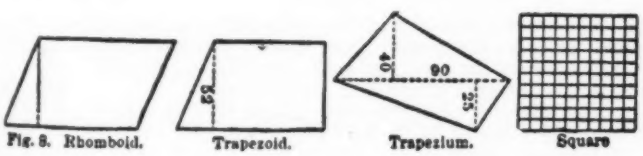


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

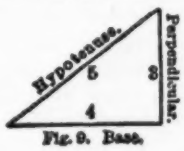


Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

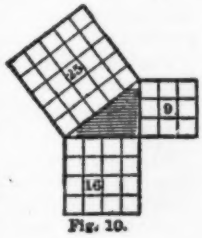


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)=16; of 3 (perpendicular)=9; the square root of their sum (25)=5, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods.
Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000+$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

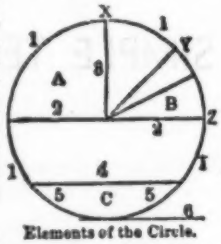
What is the diagonal of a field 35 rods square?
This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350.$
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—28 × 3 1/7 = 88 in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—144.5 × 3183 = 46 in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—20^2 × .7854 = 314.16 sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—50^2 × 3.1416 = 7854 sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

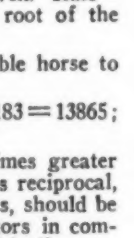
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, 43560 × .3183 = 13865; $\sqrt{13865}$ = 117¾ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

24 × .707 = 17 in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—12 × 1.414 = 17 in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—20 × 80 = 1600 × .7854 = 1256.64 sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—50 × .464 = 23.2 in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

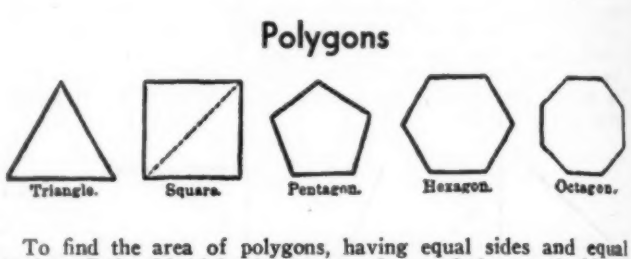
(41 + 29) = 70 × 3.1416 ÷ 2 = 110 ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

60 × 40 = 2400 × .7854 = 1885 sq. ft. nearly.

Polygons

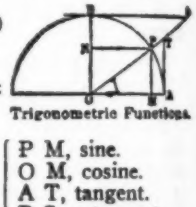


To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

30^2 × 433 = 389.7 in. T; 10^2 × 4.824 = 482.84 in. O.



Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

- **P M**, sine.
- **O M**, cosine.
- **A T**, tangent.
- **B S**, cotangent.
- **O T**, secant.
- **O S**, cosecant.
- **M A**, versed sine.
- **B N**, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—12^2 × 6 = 864.

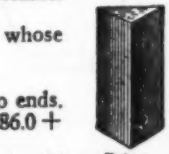
How many cubic in. in a cubic foot?

Answer—$*12^3$ = 1728.

Find cu. ft. in a cu. mile.

Answer—5280^3 = 147197952000.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?


Parallelopiped.

Answer—10½ × 3 × 1¼ = 39⅜.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

10^2 × .433 × 2 = 86.6 sq. in. in area of the two ends.

10 × 25 × 3 = 750 sq. in. area of sides. 86.0 + 750 = 836.6.

How many cubic inches in above prism, 10 by 25 inches?

Answer—10^2 × .433 = 43.3 × 25 = 1082½ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

3)549(183, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\,7/12$ sq. in., area of average base; $12\,7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\,7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

CONTENTS OF HORIZONTAL CYLINDERS

A Multiple Use Chart for Vertical as Well as Horizontal Tanks, Pipe Lines, Etc.

By J. TARRANT

Assoc. M. Inst. C. E., A. M. I. Mech. E.
Ruislip (Middlesex), England

THE alignment chart printed herewith gives a convenient method of finding the contents of cylindrical tanks placed with the axis horizontal for all depths of liquid in the tank.

It is usually the case that only a fair approximation of the tank contents is required, and the calculation by exact formula is not very readily done.

Formulas for horizontal cylindrical tanks contents are generally printed in two forms, one for use when the liquid level is above the centre and the other when the level is below the centre of the tank.

On the chart, the scale relating to the depth of liquid is continuous; that is to say, it applies whether the liquid level be in the upper or lower half of the section.

To use the chart, a straightedge is placed across the scales, and the intersections on the three scales give the related values. Line A gives the ratio of depth of liquid to the diameter of the tank; line B, the diameter of the tank in feet; and line C, the contents, in cubic feet and gallons, for each foot of length of the tank. In the example shown by the line across the chart, a tank 15 feet in diameter in which the contents are 10 feet 6 inches deep, will contain approximately 1,000 gallons per foot of length.

By using the fixed value of h/d = I, the chart also gives contents per foot of height of a cylinder with vertical axis, and also the contents of full pipes per foot of length.

Sometimes the dimensions of a tank or pipe line will not be in feet, but the chart may still be used. The contents will be in units which correspond to the dimensional units, and the scale of gallons will not apply. For example, if the diameter is taken in inches, the contents, *read on the cubic feet scale*, will be in *cubic inches* per *inch* of length.

The calculation of contents is clearly based on the area of the segment of a circle, which is what the contents scale on line C shows, and the calculation of segmental areas, in any dimensional units, may be made by use of the chart so long as the cubic feet scale is read, and units ascribed to this which correspond to the units used for the diameter. When the diameter is in feet, the area of the segment is in square feet; for meters, the area is in square meters; for inches, in square inches, and so on.

WEIGHTS AND MEASURES

Troy Weight

3.086 grains = 1 carat
24 grains = 1 dwt.
20 dwts. = 1 ounce
12 ounces = 1 pound

Used for weighing gold, silver, and jewels.

Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

The ounce and pound in this weight are the same as in Troy Weight.

Avoirdupois Weight

1 grain (Troy) = 1 grain (Apoth.) = 1 grain (Avdp.)
27 11/32 grams = 1 dram
16 drams = 1 ounce = 437.5 grains
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton
2,240 lbs. = 1 long ton
1 long ton = 1 British ton

Dry Measure

2 pints = 1 quart
1 quart = 67.2 cu. in.
1 British bushel = 1.032 U. S. bushel
8 quarts = 1 peck
4 pecks = 1 bushel

Liquid Measure

4 gills = 1 pint
16 fluid ounces = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
1 British Imperial gallon = 1.200 U. S. gallons
1 cubic foot of water contains 7.48 gallons and weighs 62.321 lb.
1 gallon = 231 cu. in.
31½ gallons = 1 barrel
2 barrels = 1 hogshead

Linear Measure

1 mil = 0.001 inch
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
5280 feet = 1 statute mile
3 miles = 1 league

Square Measure

1 circular mil = 0.7854 square mils
1,000,000 square mils = 1 square inch
144 square inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
4 roods = 1 acre = 43560 sq. ft.
30¼ sq. yds. = 1 sq. rod
40 sq. rods = 1 rood
640 acres = 1 sq. mile

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods = 1 chain
10 sq. chains or 160 sq. rods = 1 acre
36 sq. miles (6 miles square) = 1 township
43560 sq. ft. = 1 acre
640 acres = 1 sq. mile

Mariners' Measure

6.08 feet = 1 fathom
120 fathoms = 1 cable length
8.31 cable lengths = 1 nautical mile
6080 feet = 1 nautical mile
1 nautical mile = 1.15 statute mile
1 knot is a speed of 1 nautical mile per hour

Paper Measure

24 sheets = 1 quire
20 quires = 1 ream
2 reams = 1 bundle
5 bundles = 1 bale

Cubic Measure

1 cu. cm. = .061 cu. in.
27 cu. ft. = 1 cu. yd.
40 cu. ft. = 1 ton (shipping)
231 cu. in. = 1 standard gallon
2150.42 cu. in. = 1 standard bushel
1 cu. ft. = 4/5 of a bushel
1728 cu. in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)

Household Measure

60 drops = 1 teaspoon
2 teaspoons = 1 dessert spoon
3 teaspoons = 1 tablespoon
16 tablespoons = 1 cup
2 gills = 1 cup
2 cups = 1 pint

METRIC EQUIVALENTS

Linear Measure

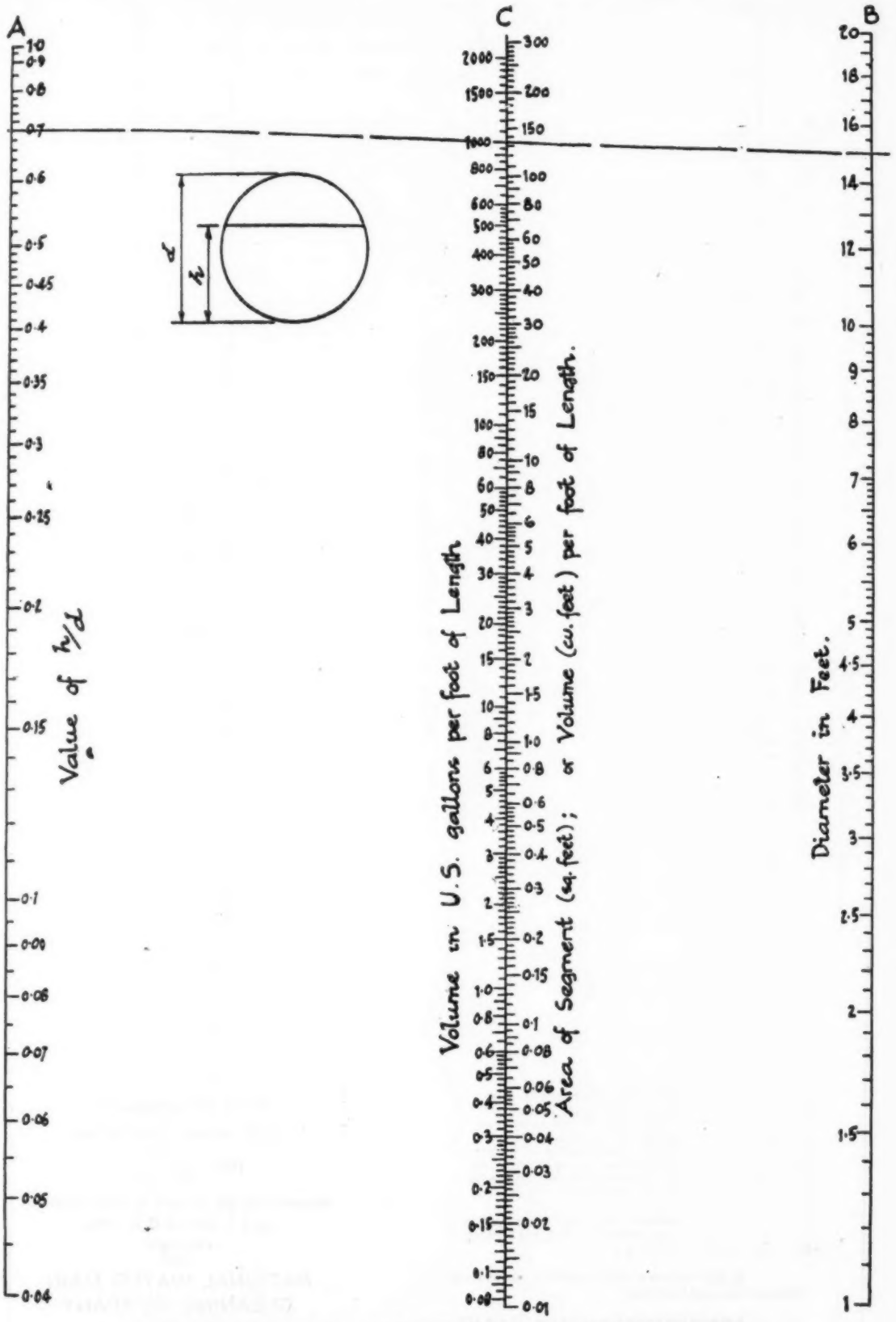
1 millimeter = 0.03937 inches
1 centimeter = 0.3937 inches
1 decimeter = 3.937 in. = 0.328 ft.
1 meter = 39.37 in. = 1.0936 yards
1 dekameter = 1.9884 rods
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters
1 foot = 3.048 decimeters
1 rod = 0.5029 dekameter
1 yard = 0.9144 meter
1 mile = 1.6093 kilometers

Square Measure

1 sq. cm. = 0.1550 sq. in.
1 sq. decimeter = 0.1076 sq. ft.
1 sq. meter = 1.196 sq. yds.
1 hectare = 2.47 acres
1 sq. kilometer = 0.386 sq. miles
1 sq. in. = 6.452 sq. cm.
1 sq. foot = 9.2903 sq. decimeters
1 sq. yard = 0.8361 sq. meter
1 sq. mile = 2.59 sq. kilometers

Weights

1 dyne = .00102 grains
1 gram = 0.03527 ounces
1 kilogram = 2.2046 lbs.
1 metric ton = 2205 lbs.
1 pound = 0.4536 kilograms
1 metric ton = 1.1023 short tons
1 ounce = 28.35 grams = 437.5 grains



CONTENTS OF HORIZONTAL CYLINDERS.

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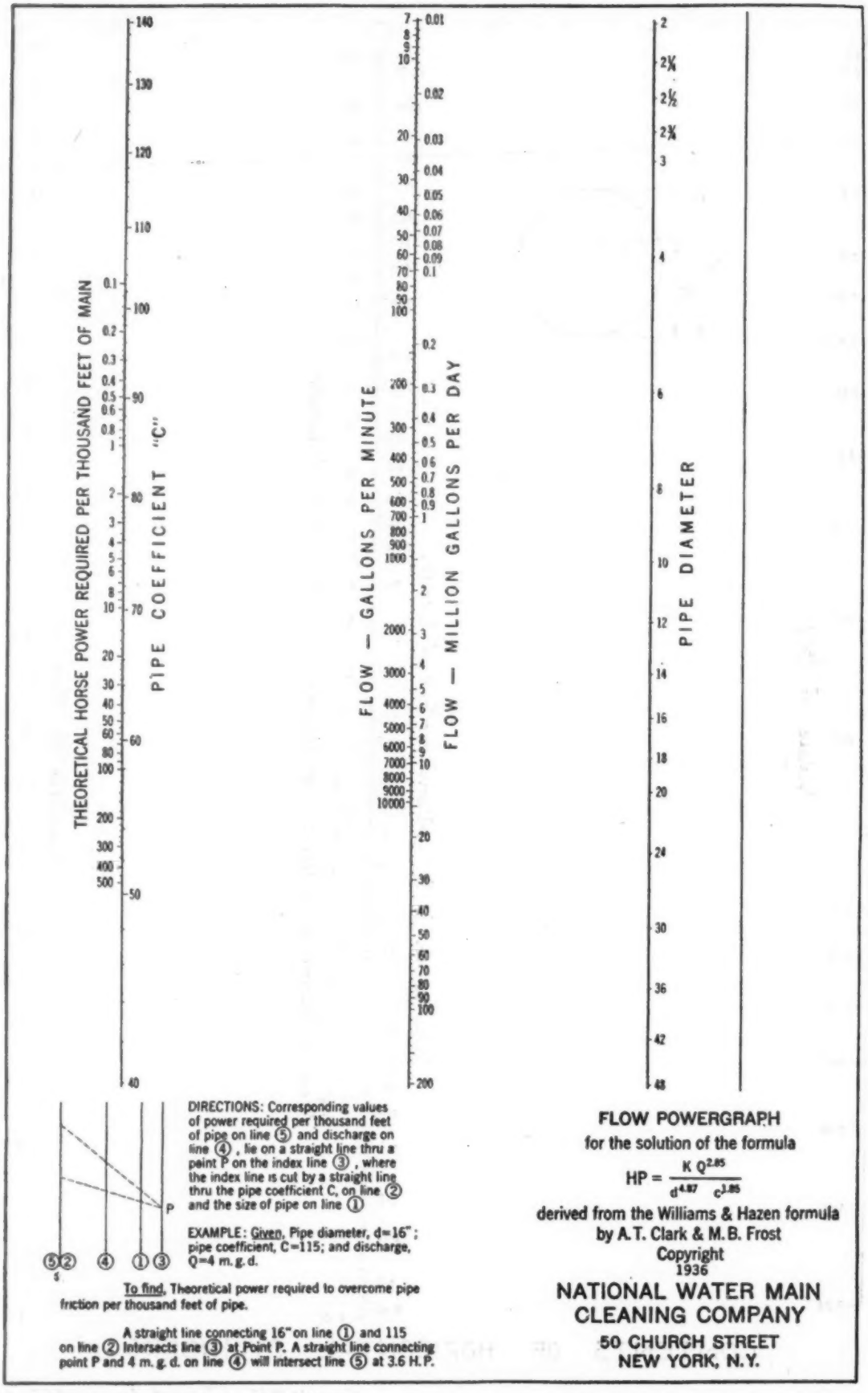
Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{2.85}}{d^{4.87}\ C^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

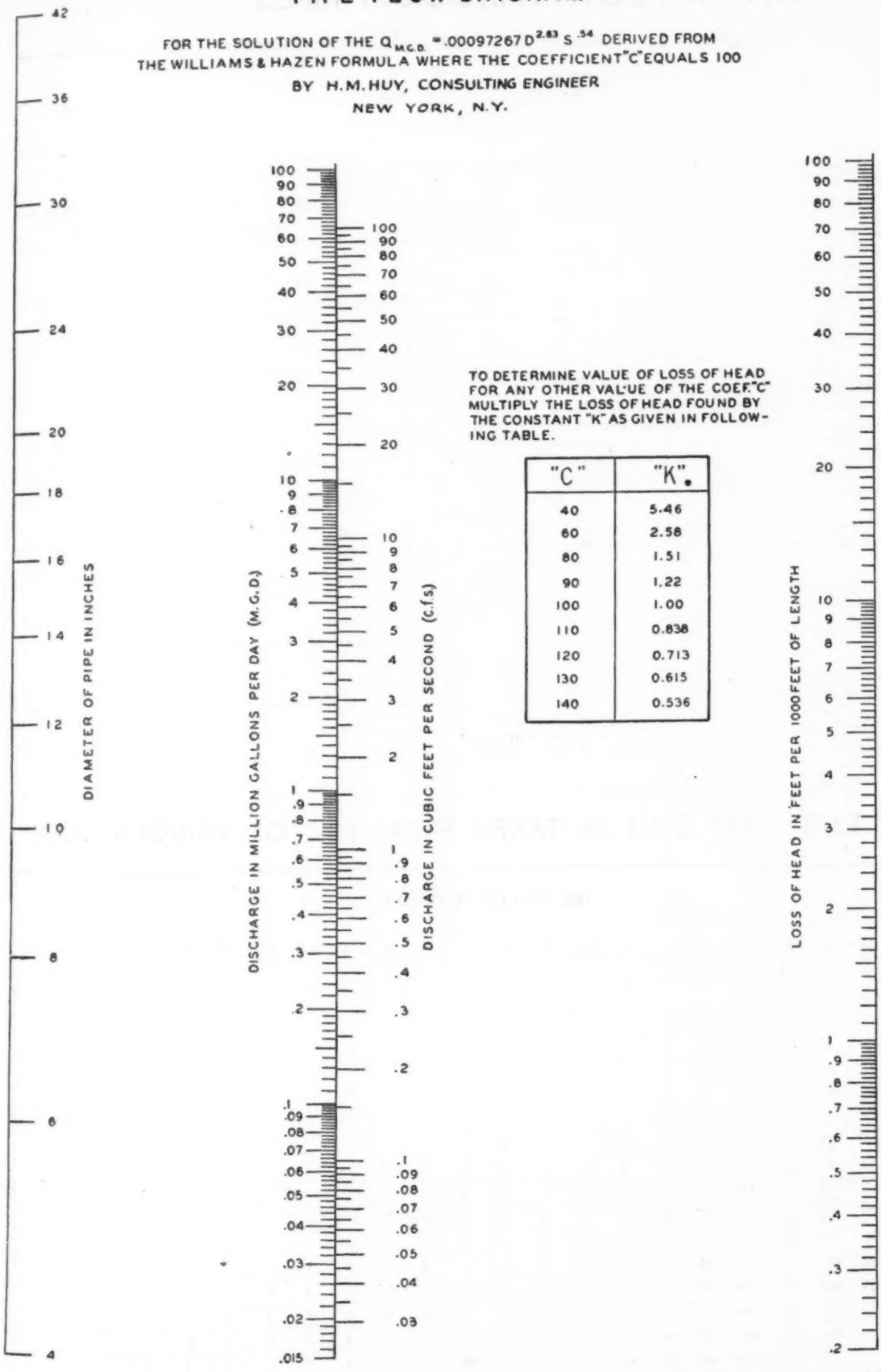
This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to De termine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\,D^{2.63}\,S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H.M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.


DIAMETER OF PIPE IN INCHES
DISCHARGE IN MILLION GALLONS PER DAY (M.G.D.)
DISCHARGE IN CUBIC FEET PER SECOND (c.f.s.)
LOSS OF HEAD IN FEET PER 1000 FEET OF LENGTH

TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K"
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

Directions for Application of This Diagram

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient due to greater roughness or smoothness of the pipe walls, is other than the base used ["C—100"] multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)

WATER FLOW THROUGH PIPES

A Nomograph for Solving the Hazen-Williams Formula

By DONALD R. KEITH
Civil Engineer
Division of Water, Columbus, Ohio

MANY hand-books co taining hydraulic data include tables for solution of the Hazen-Williams formula for flow of water in pipes. These tables are limited in their scope and give results for "V" only. Then you either figure "Q" from "V," or find some other table which shows these values.

Even with the tables it is necessary to do a certain amount of calculation, such as interpolation, etc., for seldom does your problem fit the figures in the table.

Some books contain curve charts for the solution of this formula, but only for "V." The curve charts are usually of such small scale that they are tedious to use and will not give results close enough for practical purposes since the width of a pencil point might make a very definite difference in the value of "V."

To provide a practical device for the solution of pipe discharge problems continually confronting the Division of Water and the Sewage Department of Columbus, the accompanying chart was constructed; a chart accurate enough for all practical purposes, simple enough in its operation for an individual of average intelligence to use, and furthermore, one comprehensive enough to solve every problem that had to do with the flow of water in pipes.

The Hazen-Williams formula was selected for the reason that it seems to be more generally used and accepted than any other.

To the main formula,

$$V = CR^{0.63} S^{0.54} 0.001^{-0.04}$$

was added,

$$Q = AV = 4\pi R^2 V$$

in which

V = Velocity
R = Hydraulic radius
S = Slope, or loss of head
C = Coefficient.

The value of "C" depends on the material and condition of the inner surface of the pipe. (See accompanying table of "C" values.)

In laying out the R-scale, it was immediately seen that the operation of chart would be simplified by adding the pipe diameter-in-inches-scale to the opposite side of the line by the formula R = D/4.

The Q-scale was first laid off for discharge in cubic feet per second, then to simplify, a scale showing discharge in gallons per minute was added to the opposite side of line.

The scale-modulus for the R and S-scales is 8, that is to say, the logarithmic cycle for each of these scales would equal that of an 8-in. slide rule, in the original size of chart as constructed; in the C-scale the cycle is 6.84-in.; the V-scale, 3.42-in.; and the Q-scale, 1.844-in.

The S-scale is graduated in decimals of one foot to the lineal foot. In problems involving loss of head, such as one foot loss of head in a thousand lineal feet, use the point 0.001 on the S-scale, and move the decimal period three places to the right (1.00). The S-scale is used for slope, loss of head, and pressure expressed in feet.

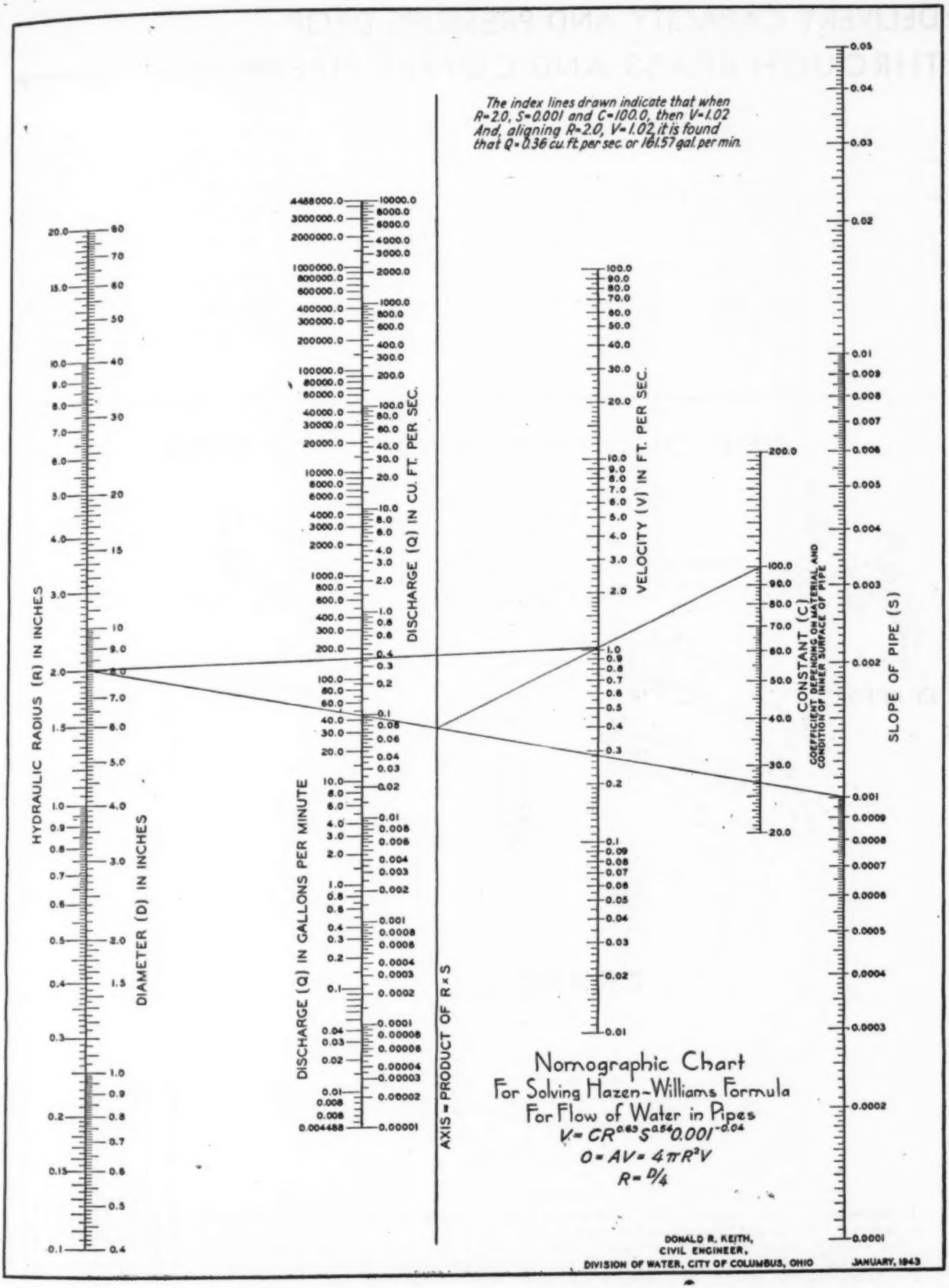
Values of "C" of course depend upon the material and condition of inner surface of pipe as noted on the accompanying chart. Tables showing values of "C" for various kinds of pipe, old and new, may be found in any hand-book of pipe data. For convenience of the user of the chart these values are listed in the following table:

"Hazen-Williams Table of Values for 'C.'"

Cast Iron Pipe, very smooth	140 to 145
" " " new, good condition	125 to 135
" " " old, good condition	100 to 125
" " " old, bad condition	60 to 100
Steel Pipe, riveted new	105 to 115
" " riveted old	90 to 105
Masonry Conduits	110 to 135
Brass, block tin, lead, glass	140 to 150

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																							
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1


The index lines drawn indicate that when R=2.0, S=0.001 and C=100.0, then V=1.02 And, aligning R=2.0, V=1.02 it is found that Q=0.36 cu. ft. per sec. or 161.57 gal. per min.
HYDRAULIC RADIUS (R) IN INCHES
DIAMETER (D) IN INCHES
DISCHARGE (Q) IN GALLONS PER MINUTE
DISCHARGE (Q) IN CU. FT. PER SEC.
AXIS = PRODUCT OF R × S
VELOCITY (V) IN FT. PER SEC.
CONSTANT (C)
COEFFICIENT DEPENDING ON MATERIAL AND CONDITION OF INNER SURFACE OF PIPE
SLOPE OF PIPE (S)
Nomographic Chart
For Solving Hazen-Williams Formula
For Flow of Water in Pipes
$V = CR^{0.63}S^{0.54}0.001^{-0.04}$
$Q = AV = 4\pi R^2 V$
$R = D/4$
DONALD R. KEITH,
CIVIL ENGINEER,
DIVISION OF WATER, CITY OF COLUMBUS, OHIO
JANUARY, 1943

Directions for using chart: Place straightedge on "D" scale at pipe diameter in inches and on "S" scale at loss of head per foot of pipe. Determine point on "Axis" line where straightedge crosses. Then place straightedge on this point on the Axis line and at Constant "C" for the pipe in question. Determine point where straightedge then crosses Velocity "V" scale. Next place straightedge on this point on "V" scale and on diameter of pipe in inches on "D" scale. Read Discharge "Q" in cfs or gpm where straightedge crosses "Q" line.

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE

This chart reveals the correct size of brass pipe or copper pipe or tubing to install for desired delivery of flow and residual pressure requirements.

Since the chart has been developed from reliable formulae, developed at Harvard University for straight runs of brass and copper pipes, it is necessary to allow something additional in the way of friction through valves, elbows and fittings. On this account, for the average service line it is good practice to add 20% to the actual length of run of pipe to compensate for loss of head through valves and fittings.

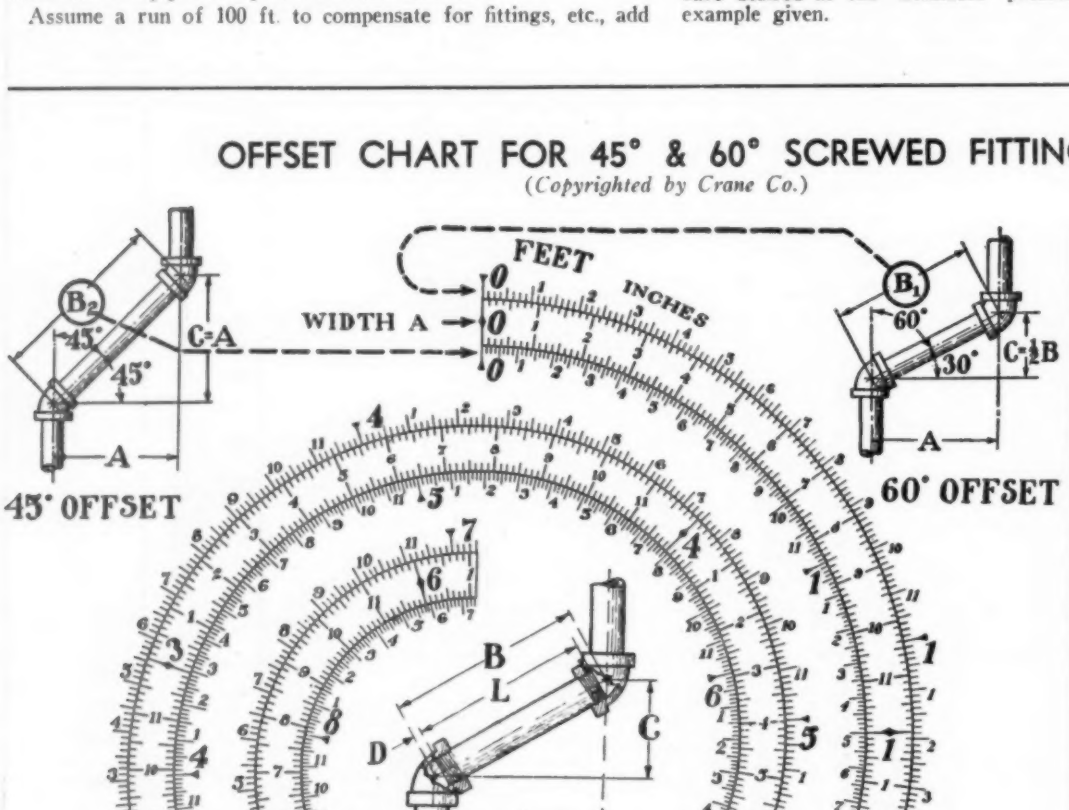
Example: There is an available pressure drop of 30 lbs., and the minimum delivery requirement at fixtures is 35 gals./ min. What size of pipe is required for this service?

Assume a run of 100 ft. to compensate for fittings, etc., add the 20% to secure an "indicated" run of 120 ft. From the 120 ft. point on the base line run up to intersect the down slanting line representing 1 in. pipe; then to the right to the 30 lb. up slanting pressure line; then up to the G.P.M. line. The answer is 36 gals./min. If the ¾ in. size had been tried the result would have been only 17 gals./min. delivery with a 30 lb. pressure available at the main. On the other size an 1¼ in. line will deliver twice the requirement—i. e., 70 gals./min. Or, for the 35 gal. rate of delivery only 10 lbs. of pressure would be required.

It is evident, therefore, that the chart will reveal the proper size of pipe to deliver a required flow with any desired residual pressure at the outlet. In this case use the difference between the normal minimum pressure at the main and the residual pressure desired as the "available" pressure and proceed as in the example given.

OFFSET CHART FOR 45° & 60° SCREWED FITTINGS

(Copyrighted by Crane Co.)



Pipe size...	⅛"	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"
45° deduct.	.....	¾"	⅞"	¾"	1"	1⅛"	1⅜"	1⅝"	2"	2"	2⅜"
60° deduct.	.....	.....	.....	1"	1⅛"	1⅜"	1⅝"	2"	2⅜"	2½"	3"
Pipe size...	3½"	4"	4½"	5"	6"	7"	8"	9"	10"	12"	
45° deduct.	2⅝"	3⅛"	3⅜"	3¾"	4⅜"	5¼"	5⅞"	6⅝"	7⅜"	8¾"	
60° deduct.	.....	3⅞"	.....	4⅝"	5⅝"	6⅝"	9⅛"	.....	9⅛"	.....	

Note—The above figures represent 2xD. To find D divide by 2.

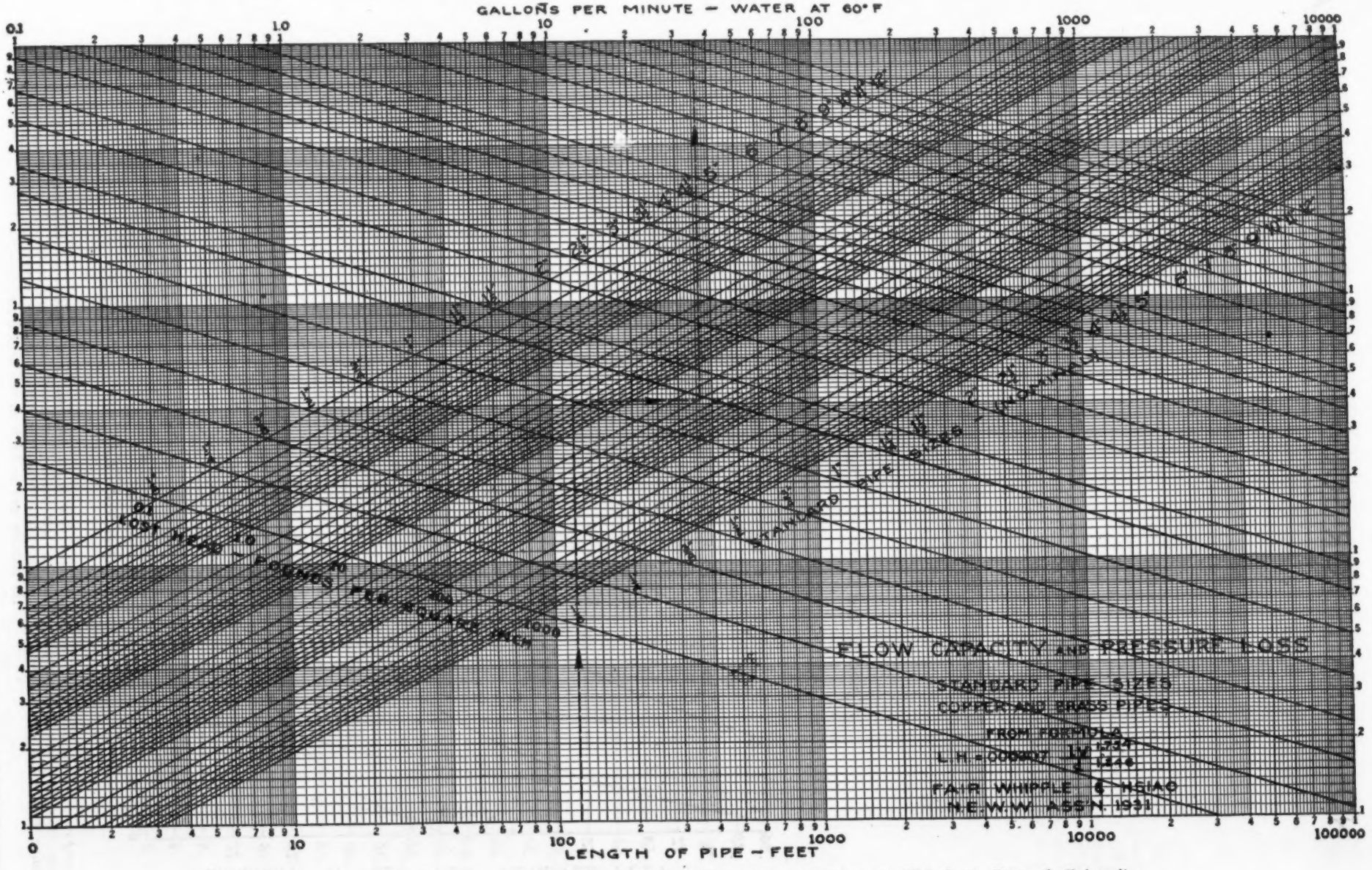
Directions

To determine the actual length of pipe, L, to use for length B, find in the table on right the amount to deduct for the desired pipe size and subtract it from length B.

For example, using the above chart, a 45° offset of width 4'-2⅛" (A) gives the length of run B as 5'-10⅞" center to center. If it is a 2" pipe then the table indicates the amount to deduct is 2". Subtracting this from 5'-10⅞" gives 5'-8⅞" as the length of pipe to cut (L).

Note—The above figures represent 2xD. To find D divide by 2.

DELIVERY CAPACITY AND PRESSURE DROP THROUGH BRASS AND COPPER PIPE



A chart developed by the Brass and Copper Research Association from formulae established at Harvard University

NOMOGRAPH FOR SOLVING MANNING'S FORMULA

By PAUL McH. ALBERT

Shoecraft, Drury & McNamee, Engrs., Ann Arbor, Mich.

THE accompanying nomographic chart presents a simple, rapid, and practical means of solving Manning's Formula for the flow of water in pipes and open channels.

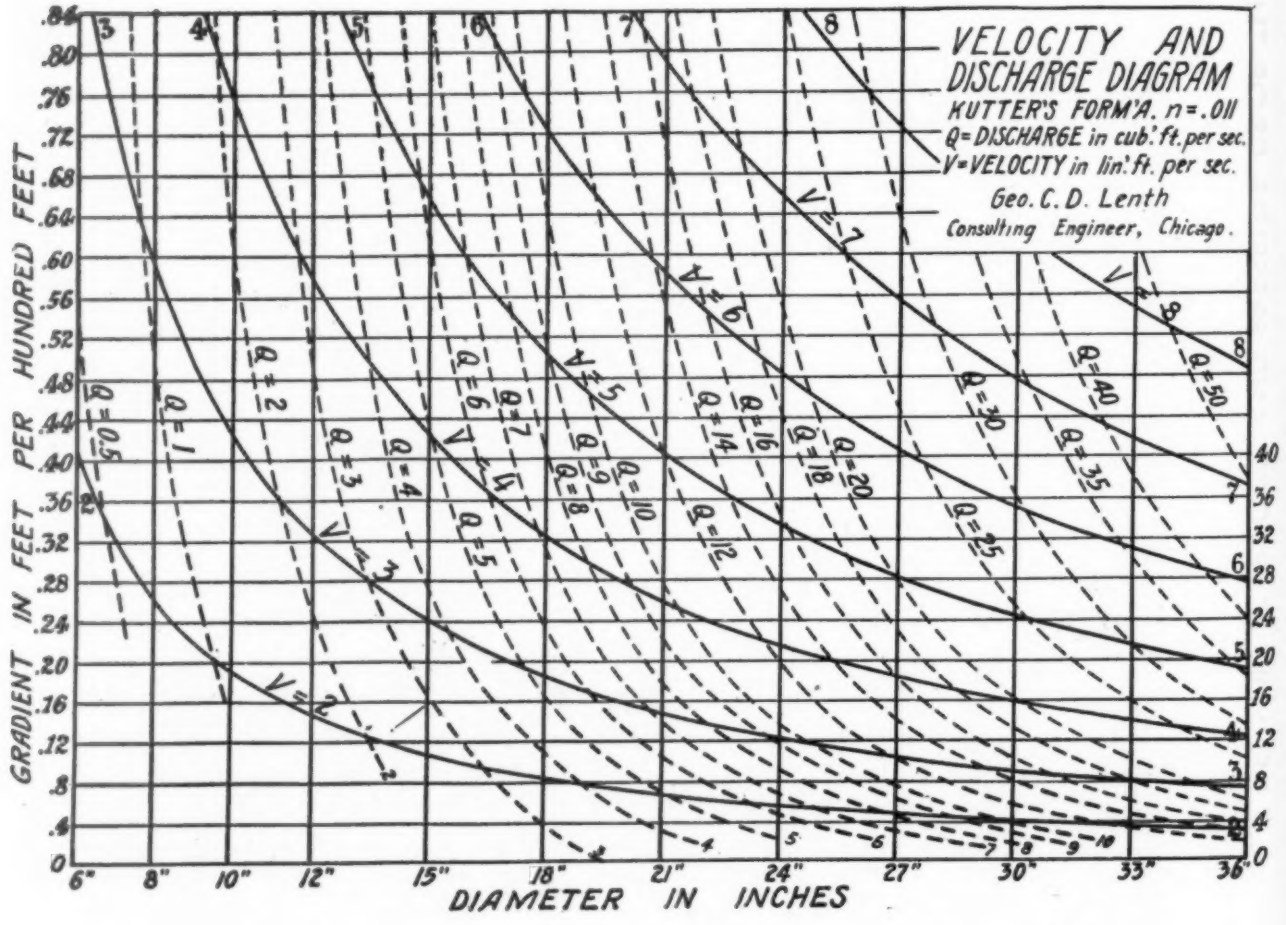
Snap analysis of problems involving this formula will be more accurate and quicker when using this nomograph inasmuch as only two or three motions are required to arrive at an answer.

If the problem entails considerable study, many different solutions may be rapidly tabulated. The effect of the coefficient "n" on the other variables as determined from the nomograph is a valuable aid for the entire range is included.

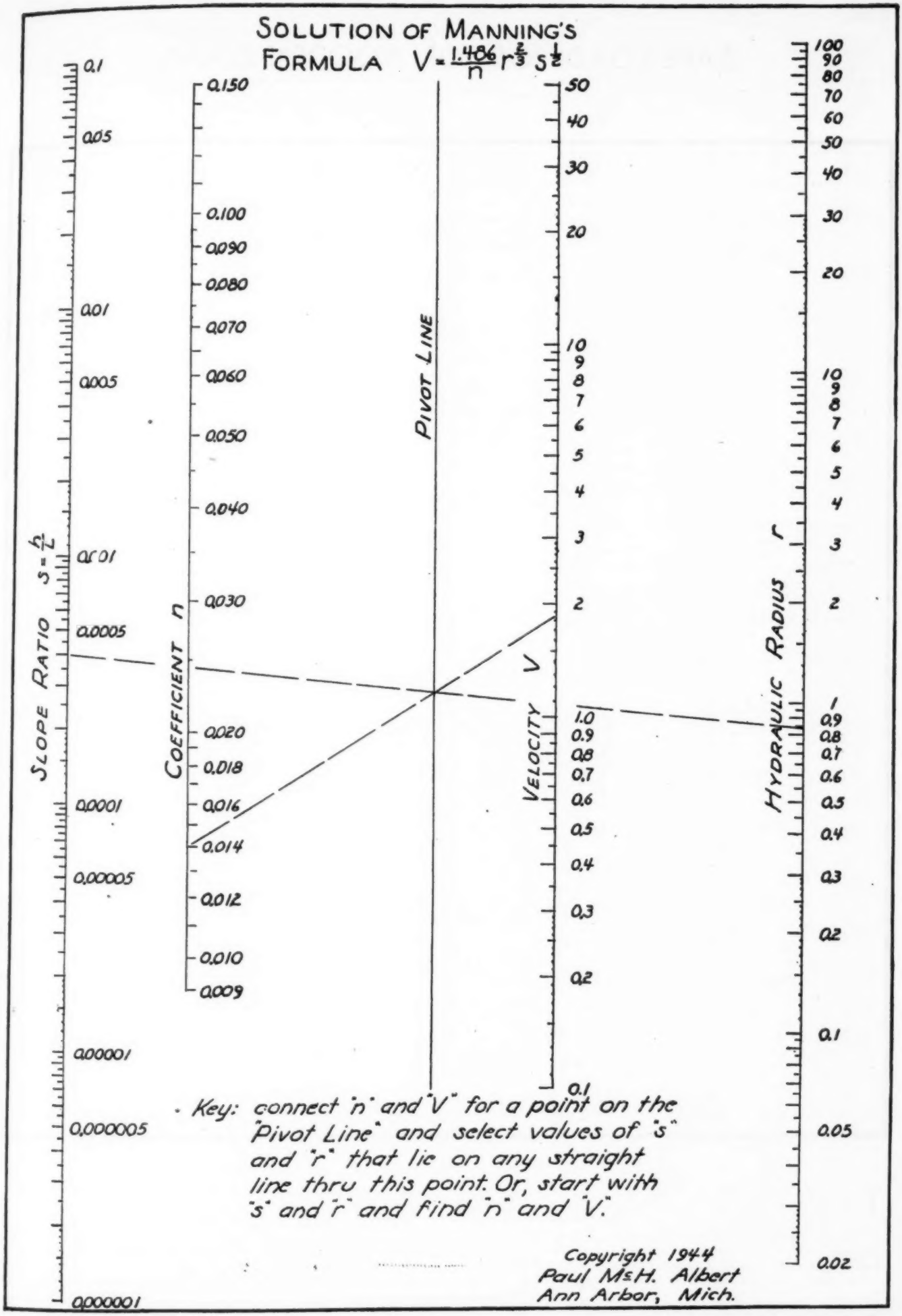
For use in checking previous designs this chart will be found to be valuable and make possible rapid checks inasmuch as it covers a wide range of all the variables. Directions for using the nomograph are given in the key at the bottom of the chart.

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub'. ft. per sec.
V=VELOCITY in lin'. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)



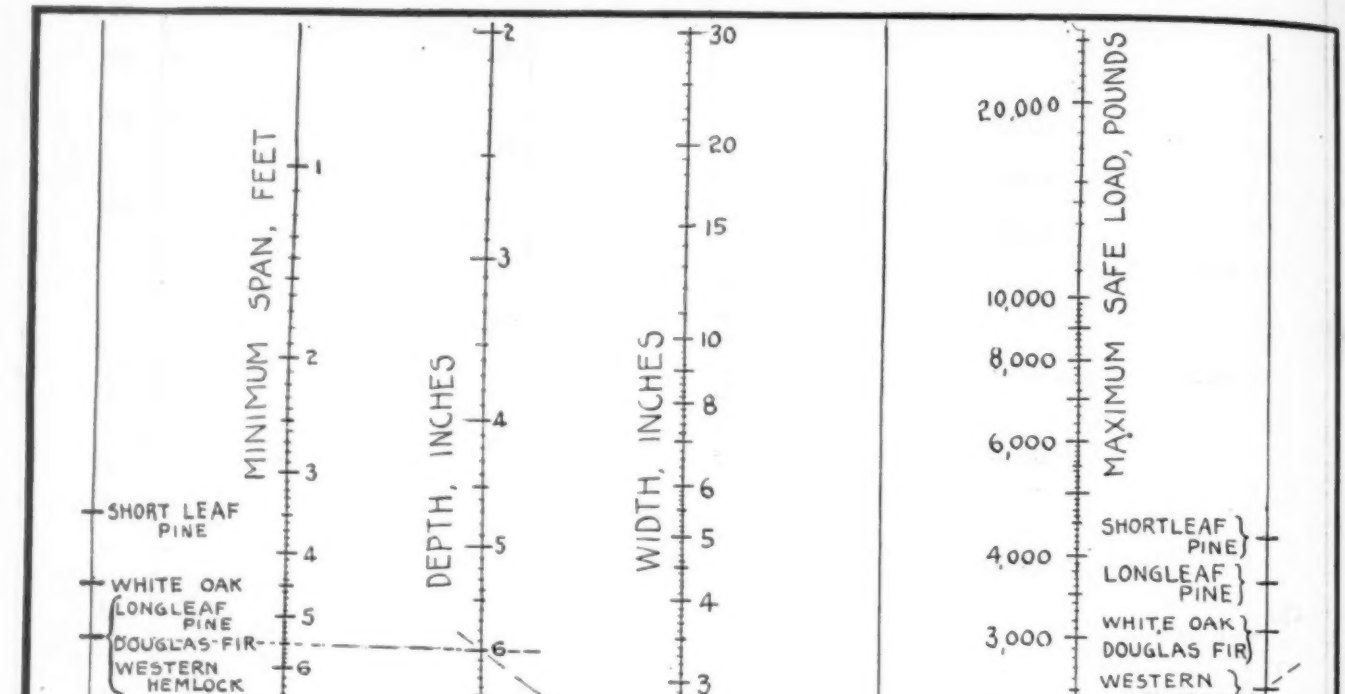
Key: connect "n" and "V" for a point on the "Pivot Line" and select values of "s" and "r" that lie on any straight line thru this point. Or, start with "s" and "r" and find "n" and "V".

Copyright 1944
Paul McH. Albert
Ann Arbor, Mich.

Nomograph for Solving Manning's Formula

SAFE LOADINGS FOR WOODEN BEAMS

Contributed by W. F. Schaphorst, M.E.



THE above chart will be found handy for many purposes—in the selection of safe beams made of ordinary woods such as shortleaf white pine, white oak, longleaf pine, Douglas fir, western hemlock, white pine, and spruce. The chart is based on data adopted by the American Railway Engineering Association for safe, uniformly loaded wooden beams of rectangular section.

Example: It is desired to hold 200 lb. per foot on a wooden beam of 2 in. by 6 in. western hemlock over a span of 5 ft. Will the beam be safe?

Run a straight line from the point in column A opposite "western hemlock" over to the depth 6 in column C. The intersection with column B shows the minimum span to be 5.5 ft. The beam will therefore be safe as regards span.

Then from the depth 6 in column C run a straight line through

the width 2 in column D and locate the intersection in column F. Then from that point of intersection run a straight line over to the point in column G opposite "western hemlock." The answer is found at the intersection with column F and is 1,600 pounds.

Since it is desired to hold only 5 × 200 or 1000 lb. on the 5 ft. beam, and since the beam will actually hold 1,600 lb., it certainly is amply safe. In fact, the chart shows that a beam made of white pine or spruce would be safe under this load.

Inversely, the chart may be used for finding any unknown factor or factors. If the kind of wood and the span are known, the first straight line through columns A, B and C gives the minimum depth of beam which must be used. If the width of beam is unknown, the line through the columns E, F, G is located next, and lastly the line through columns C, D, E gives the minimum width of beam in column D.

The weight of the beam itself is included in the safe load given in column F, hence the user of the chart need not worry about that factor.

SAFE LOADINGS FOR I-BEAMS

Contributed by W. F. Schaphorst, M.E.

THE accompanying chart reveals how much any ordinary I-Beam will hold under the very *worst* condition, with the load concentrated in the middle of the span as shown by the sketch on the chart. The chart, for the sake of safety, is based on concentrated loading.

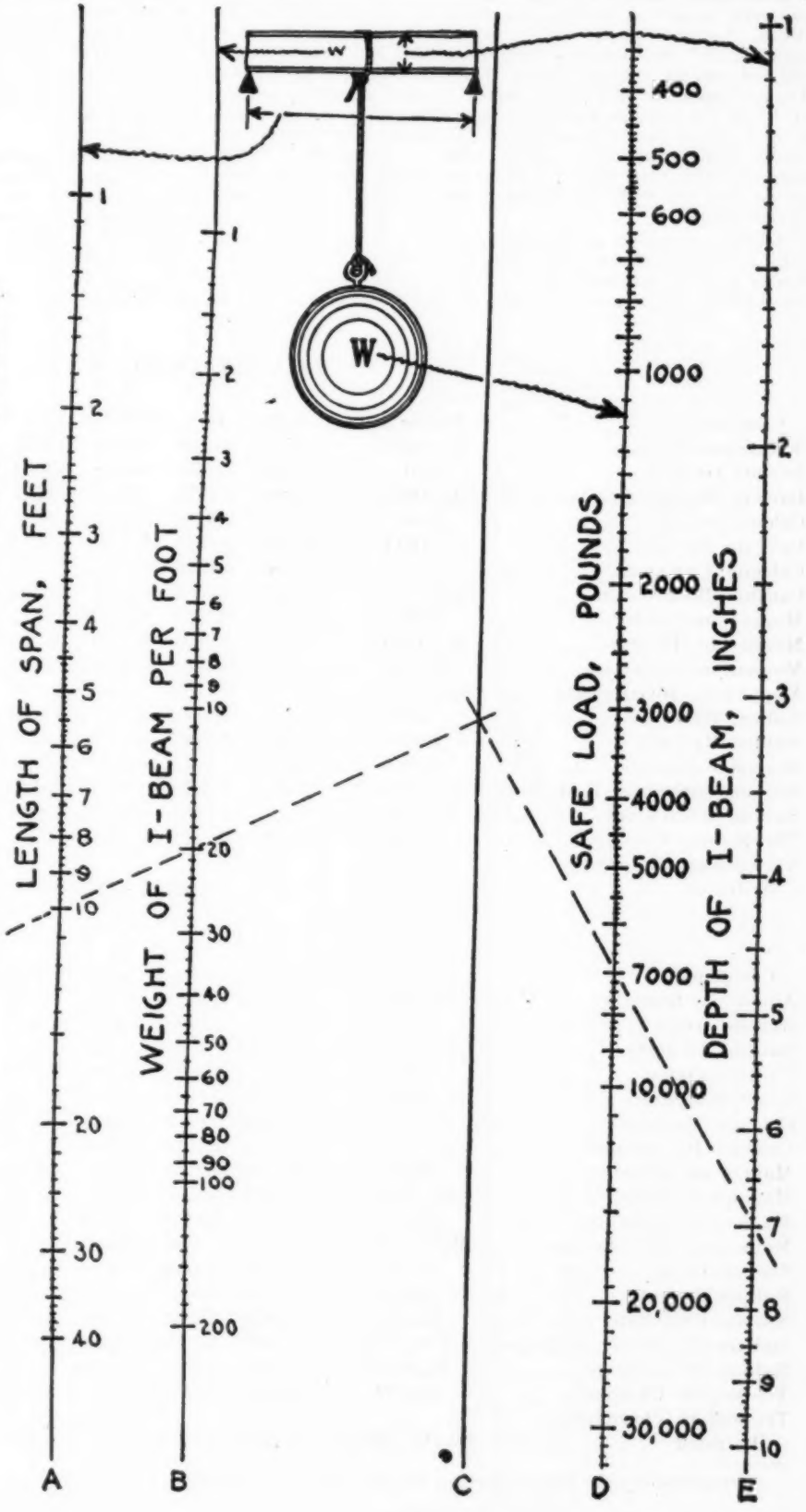
Let us suppose that a weight of 4,000 lbs. must be supported. A 7-inch I-Beam, weighing 240 lbs., is available. It is 12 feet long, and therefore weighs 20 lbs. per foot. The minimum distance between supports that can be obtained for the lifting operation is 10 feet. Is the I-Beam strong enough to lift the 4,000-lb. load?

The Answer

Run a straight line through the 10-ft. (column A) and the 20-lb. (column B) and locate the intersection in column C. Then, from that intersection in column C, run over to the 7-in. (column E). The intersection through column D shows that the I-Beam will support 7,000 lbs. Since the load to be lifted is only 4,000 lbs. the beam is amply strong. In fact, the reader can easily find, by applying the chart, that a 4-inch I-Beam, all other conditions being the same, would safely support the load of 4,000 lbs.

Similarly, it is easy to ascertain the maximum allowable span when the factors in columns B, D and E are known. Or, the necessary weight per foot of I-Beam may be determined when the factors in columns A, D and E are known. Lastly, the depth of beam is determinable when the factors in column A, B and D are known.

For loads that are "uniformly distributed"—not concentrated—the safe loads in column D may be multiplied by two. Thus, the above described beam will support a uniformly distributed load of 14,000 lbs., or 1,400 lbs. per running foot.



ALKALINITY EQUIVALENTS

AMONG the mineral compounds present in natural waters, Calcium Carbonate is the most ubiquitous. Partly for this reason and partly because its molecular weight at the time, was thought to be exactly 100, this compound was chosen as the standard to be employed in the measurement of alkalinity and hardness.

With more accurate determination of atomic weights, the molecular weight of Calcium Carbonate is now assumed to be 100.08. Very obviously, tables earlier prepared under the assumption that the molecular weight was 100 will have a small and not entirely negligible error if the true weight be 100.08. The accompanying table, based upon the newer molecular weight of 100.08 for Calcium Carbonate, are arranged in such manner as to facilitate comparisons against other substances having different values of alkalinity. These values are presented as being more accurate than those appearing in earlier tables computed on the old 100 molecular weight value assumed for Calcium Carbonate.

A brief explanation of how the tables may be used follows.

In the sixth column, sixth line, the unity of Calcium Carbonate may be compared directly against every other factor in the column. For instance, one part of alkalinity, due to Calcium Carbonate, is the exact equivalent, in alkalinity value, to that which would be imparted by 1.6196 of Calcium Bicarbonate; 0.7403 of Calcium Hydroxide; 0.8424 of Magnesium Carbonate; 1.0590 of Sodium Carbonate (dehydrated), etc.

Along the line, right or left, a different comparison may be made. The molecular weight, for instance, of Calcium Bicarbonate, is in excess of that of Calcium Carbonate. Therefore, it takes more Calcium Bicarbonate to produce a given alkalinity than it does of Calcium Carbonate, and it is found that for an equal weight of Calcium Bicarbonate the alkalinity value as compared against Calcium Carbonate is only 0.6174 parts. On the other side an equal weight of Calcium Hydrate will have an alkalinity value of 1.3506 parts; Sodium Hydroxide 1.2508—and so on.

From the foregoing it is seen that the compounds in these tables may be compared in two different ways against the Calcium Carbonate Standard for alkalinity, or against any other compound in the table. For instance, under the heading Sodium Hydroxide (NaOH) it is noted that one part is equal in alkalinity value to 1.3247 parts of Sodium Carbonate (Soda Ash); and, further, that one part of Sodium Carbonate is only equal to 0.9442 parts of Calcium Carbonate in raising alkalinity values.

ALKALINITY EQUIVALENTS*

Compound	Formula	$Al_2(OH)_6$	BaO	$Ba(OH)_2$	CaO	$Ca(OH)_2$	$CaCO_3$	$CaH_2(CO_3)_2$	MgO	$Mg(OH)_2$
Aluminum Hydrate	$Al_2(OH)_6$	*1.0000*	0.3390	0.3034	0.9271	0.7017	0.5195	0.3207	1.2895	0.8913
Barium Oxide	BaO	2.9494	*1.0000*	0.8948	2.7734	2.0697	1.5323	0.9461	3.8035	2.6289
Barium Hydrate	$Ba(OH)_2$	3.2959	1.1174	*1.0000*	3.0559	2.3128	1.7123	1.0572	4.2503	2.9377
Calcium Oxide	CaO	1.0785	0.3656	0.3272	*1.0000*	0.7568	0.5603	0.3459	1.3908	0.9613
Calcium Hydrate	$Ca(OH)_2$	1.4250	0.4831	0.4323	1.3212	*1.0000*	0.7403	0.4571	1.8376	1.2701
Calcium Carbonate	$CaCO_3$	1.9247	0.6525	0.5839	1.7845	1.3506	*1.0000*	0.6174	2.4821	1.7155
Calcium BiCarbonate	$CaH_2(CO_3)_2$	3.1174	1.0569	0.9458	2.8904	2.1876	1.6196	*1.0000*	4.0202	2.7786
Magnesium Oxide	MgO	0.7754	0.2629	0.2352	0.7189	0.5441	0.4028	0.2487	*1.0000*	0.6911
Magnesium Hydrate	$Mg(OH)_2$	1.1219	0.3803	0.3403	1.0402	0.7873	0.5828	0.3598	1.4468	*1.0000*
Magnesium Carbonate	$MgCO_3$	1.6216	0.5498	0.4920	1.5035	1.1379	0.8425	0.5201	2.0912	1.4454
Magnesium BiCarbonate	$MgH_2(CO_3)_2$	2.8143	0.9541	0.8538	2.6094	1.9749	1.4621	0.9027	3.6293	2.5085
Sodium Oxide	Na_2O	1.1922	0.4042	0.3617	1.1054	0.8366	0.6194	0.3824	1.5375	1.0627
Sodium Hydrate	NaOH	1.5387	0.5217	0.4668	1.4267	1.0798	0.7994	0.4935	1.9843	1.3715
Sodium Carbonate	Na_2CO_3	2.0385	0.6911	0.6184	1.8900	1.4305	1.0590	0.6538	2.6288	1.8169
Sodium Carbonate, Hydrated	$NaCO_3,10H_2O$	5.5033	1.8658	1.6697	5.1025	3.8619	2.8592	1.7653	7.0969	4.9052
Sodium BiCarbonate	$NaHCO_3$	3.2312	1.0955	0.9803	2.9958	2.2674	1.6787	1.0364	4.1669	2.8800
*Tri-Sodium Phosphate	Na_3PO_4	2.1028	0.7129	0.6380	1.9497	1.4756	1.0925	0.6745	2.7118	1.8743
Tri-Sodium Phosphate, Hydrated	$Na_3PO_4,12H_2O$	4.8747	1.6527	1.4790	4.5197	3.4207	2.5326	1.5636	6.2863	4.3449

Compound	Formula	$MgCO_3$	$(CO_3)_2$	Na_2O	NaOH	Na_2CO_3	Na_2CO_3, $10H_2O$	$NaHCO_3$	Na_3PO_4	Na_3PO_4 $12H_2O$
Aluminum Hydrate	$Al_2(OH)_6$	0.6166	0.3553	0.8387	0.6498	0.4905	0.1817	0.3094	0.4755	0.2151
Barium Oxide	BaO	1.8187	1.0480	2.4737	1.9167	1.4468	0.5359	0.9128	1.4025	0.6050
Barium Hydrate	$Ba(OH)_2$	2.0324	1.1711	2.7643	2.1419	1.6168	0.5989	1.0200	1.5672	0.6761
Calcium Oxide	CaO	0.6650	0.3832	0.9046	0.7009	0.5290	0.1959	0.3337	0.5128	0.2212
Calcium Hydrate	$Ca(OH)_2$	0.8787	0.5063	1.1952	0.9260	0.6990	0.2589	0.4410	0.6776	0.2923
Calcium Carbonate	$CaCO_3$	1.1869	0.6839	1.6143	1.2508	0.9442	0.3497	0.5956	0.9152	0.3948
Calcium BiCarbonate	$CaH_2(CO_3)_2$	1.9223	1.1076	2.6146	2.0259	1.5292	0.5664	0.9647	1.4824	0.6395
Magnesium Oxide	MgO	0.4781	0.2755	0.6503	0.5039	0.3803	0.1409	0.2399	0.3687	0.1590
Magnesium Hydrate	$Mg(OH)_2$	0.6918	0.3986	0.9409	0.7291	0.5503	0.2038	0.3472	0.5334	0.2301
Magnesium Carbonate	$MgCO_3$	*1.0000*	0.5762	1.3601	1.0538	0.7955	0.2946	0.5018	0.7711	0.3326
Magnesium BiCarbonate	$MgH_2(CO_3)_2$	1.7354	*1.0000*	2.3604	1.8289	1.3806	0.5113	0.8709	1.3382	0.5773
Sodium Oxide	Na_2O	0.7352	0.4236	*1.0000*	0.7748	0.5848	0.2166	0.3689	0.5669	0.2445
Sodium Hydrate	NaOH	0.9488	0.5467	1.2906	*1.0000*	0.7548	0.2796	0.4762	0.7317	0.3156
Sodium Carbonate	Na_2CO_3	1.2570	0.7243	1.7097	1.3247	*1.0000*	0.3704	0.6308	0.9693	0.4181
Sodium Carbonate, Hydrated	$NaCO_3,10H_2O$	3.3936	1.9554	4.6157	3.5764	2.6996	*1.0000*	1.7031	2.6169	1.1289
Sodium BiCarbonate	$NaHCO_3$	1.9925	1.1481	2.7100	2.0998	1.3850	0.5871	*1.0000*	1.5364	0.6628
Tri-Sodium Phosphate	Na_3PO_4	1.2967	0.7471	1.7637	1.3665	1.0315	0.3821	0.6504	*1.0000*	0.4313
Tri-Sodium Phosphate, Hydrated	$Na_3PO_4,12H_2O$	3.0059	1.7320	4.0885	3.1679	2.3913	0.8857	1.5078	2.3181	*1.0000*

* Prepared by the late C. Arthur Brown, of Lorain, Ohio.

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	9	63.62	475.9	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9-6	70.88	530.2	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	10	78.54	587.5	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10-6	86.59	647.7	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	11	95.03	710.9	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11-6	103.9	777.0	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8.22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19.06	97	42.01	150	64.97	208	87.93	256	110.89	900	389.86
45	19 49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

Theoretical Horsepower

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

HEAD IN FEET

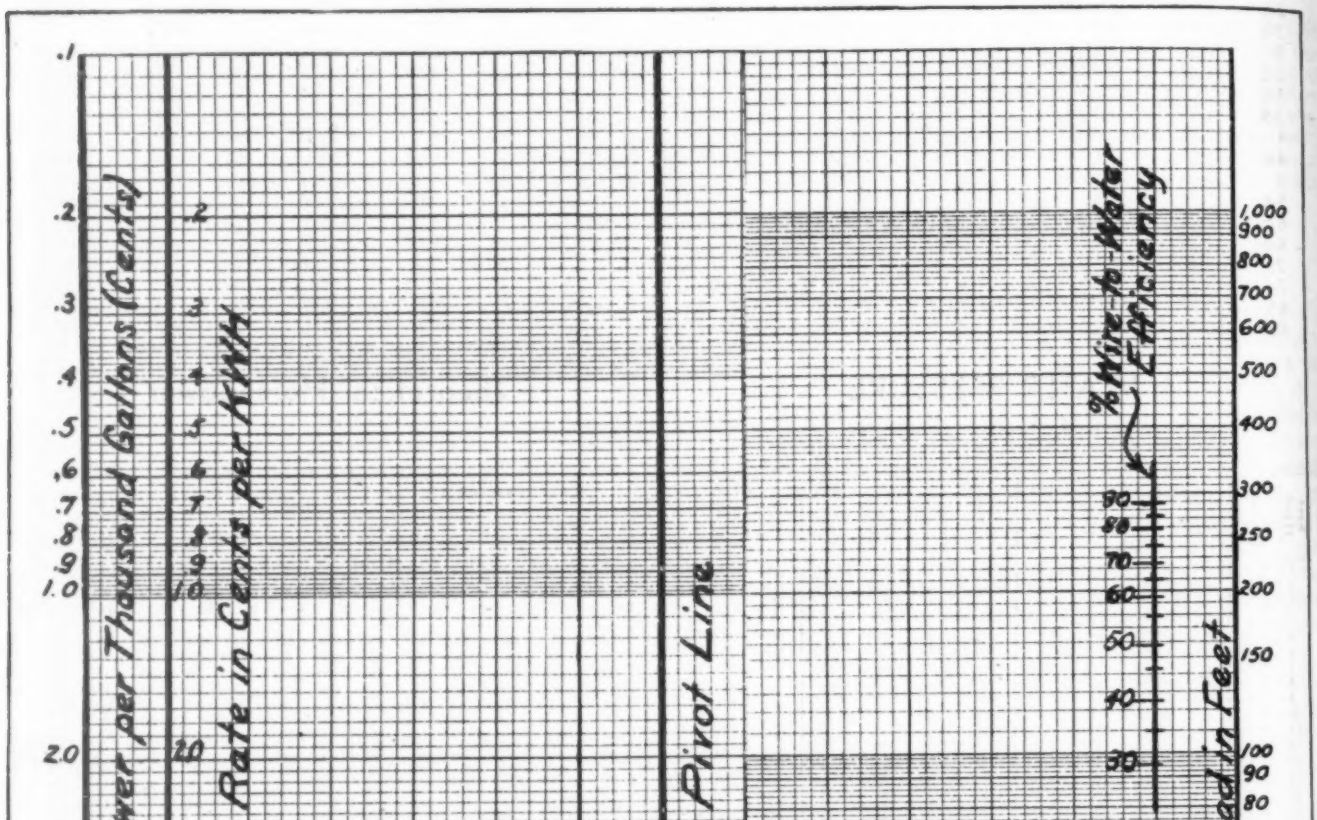
Gallons per minute — Ft.	10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	.47	.57	.68
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1 51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2.52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6.31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6 06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10.60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10.10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10.10	11.36	12.63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10.10	12.63	15.15	17.67	20.20	22.72	25.25	30.30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{\text{3960 x Effy. of the pump}}$$

CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*



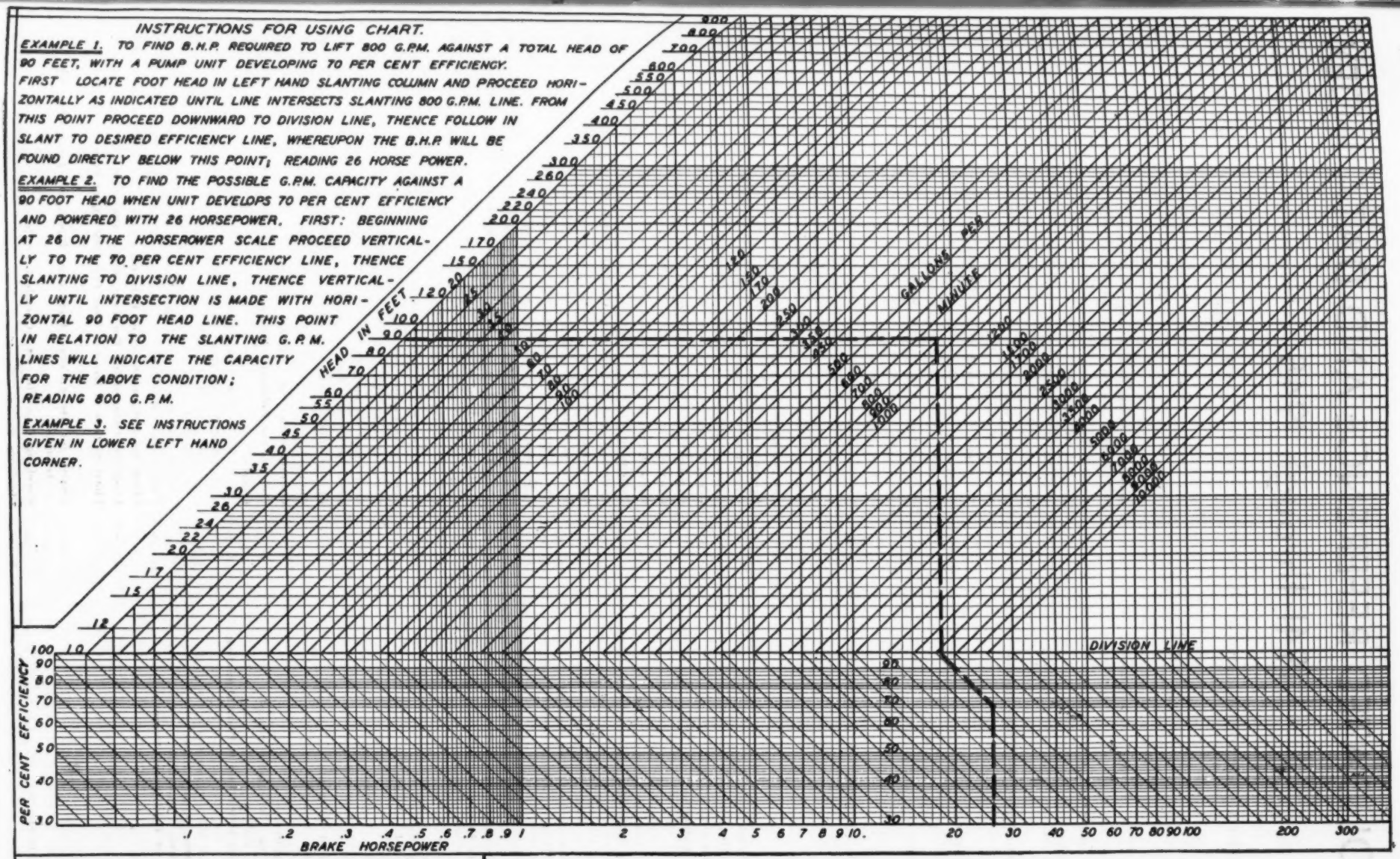

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

CONSOLIDATED REFERENCE AND DATA INDEX
1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

A

Accounted for Water and Unbilled Revenue..... 109
Accounting Practices, Municipal Depreciation..... 15
Accounts, Joint Administration and Collection of Water and Sewer .....('44) R-161
Accurate Levelling and Aligning by Simple Method..... 46
Activated Carbon..... 125
Activated Sludge—
Air Diffuser Plate Cleaning.....('43) 265
Air Diffuser Servicing.....('43) 266
Air Diffusion Media.....('44) R-222
Air Distribution Systems.....('44) R-205
Bulking .....('42) 203, ('43) 239
Bulking Control..... 212
Cleaning Plates.....('44) R-222
Density—Volume Ratio.....('44) R-252
Diffused Air Aeration.....('44) R-211
Fundamentals of Process..... 197
Mechanical Aeration..... 203
Purging Plates with Chlorine.....('44) R-221
Sludge Index Test.....('44) Mag. 222
Thickening .....('43) 243
Activated Sludge Bulking.....('42) 203
Activated Sludge Bulking.....('43) 239
Activated Sludge Thickening.....('43) 243
Administration and Collection of Joint Water and Sewer Accounts .....('44) R-161
Aero-Chlorination for Degreasing Sewage.....('43) 211
Air and Chlorine for Degreasing Sewage.....('43) 211
Air, Dewatering Mains with Compressed.....('43) 110
Air Diffuser Plate Cleaning.....('43) 265
Air Diffuser Servicing, Porous Plate.....('43) 266
Air Diffuser Plate Purging with Chlorine.....('44) R-221
Air-Diffusion Media, Economics of Cleaning.....('44) R-222
Air Distribution Systems for Activated Sludge Plants.....('44) R-205
Air Flushing of Small Mains.....('44) R-110
Air-Gas Mixtures, Limits of Flammability.....('43) 258
Air Leak Costs.....('43) 282
Air-Lift Subaqueous Trencher..... 116
Air Release for Sewage Pumps..... 256
Air Sniffer Corrects Pump Pounding.....('42) 74
Algae Control.....('44) R-127
Algae, Control of.....('43) 139
Aligning and Levelling Method..... 46
Alkalinity Effects on pH.....('43) 287
Alkalinity Equivalents 282
Alkalinity, pH and CO_2, Diagram.....('43) 286
Ammonia, Anhydrous.....('41) 117
Ammoniation, Aqua.....('41) 95
Analyses of Sewage and Effluents.....('42) 250
Analyses of Water, Interpretation of Chemical.....('43) 123
Anhydrous Ammonia.....('41) 117
Anthrafilt and Its Significance..... 145
Apparatus for Collecting Flocculated Samples.....('43) 161
Application of Copper Sulfate..... 119
Application of the Sludge Index Test to Plant Operation.('44) Mag. 222
Aqua Ammoniation.....('41) 95
Aquatic Vegetation and Micro-organisms, Control of.....('44) R-127
Areas of Circles, Squares, Square Roots.....('44) R-264
Areas, Volumes, Surfaces, Calculation of..... 267
Automatic Operation of Centrifugal Pumps... .....('43) 40

B

Bells, Submergence and Spacing of.....('41) 25
Bending Pipes.....('44) R-111
Books on Water Works and Sewerage.....('44) R-15
Bicarbonate and Carbonate Alkalinity Effects on pH.....('43) 287
Bids, Pump: Method of Evaluation.....('43) 43
Blotting Out Waste..... 118
Blowing Out Service Lines.....('43) 112
Branches—Number and Size Main Will Supply.....('43) 282
Brass and Copper Pipe, Capacity and Pressure Drop Through.. 276
Brassert Automatic Self Cleaning Strainers.....('42) 114
Buildings, Regulating Water Piping Within..... 19
Bulking of Activated Sludge.....('42) 203
Bulking of Activated Sludge.....('43) 239
Bulking Control, Activated Sludge..... 212

C

Calculation of Areas, Volumes, Surfaces Reduced to Simple Terms. 267
Calgon Treatment..... 151
Capacities, Carrying, Relative for Pipe Lines..... 266
Capacity and Pressure Drop, Brass and Copper Pipe..... 276
Capacity, Head, Efficiency, Horsepower..... 285
Capacity of Cylindrical Tanks..... 283
Capacity, Maintenance of Water Well.....('44) R-112
Capacity of Reciprocating Pumps (Nomograph).....('42) 274
Carbon, Activated 125
Carbonate and Bicarbonate Alkalinity and pH.....('43) 287
Care and Maintenance of Gate Valves..... 105
Carrying Capacity of Pipe Lines..... 266
Cast Iron Mains, Lining in Place with Cement Mortar..... 96
Cast Iron Pipe Cutting.....('44) R-75
Cathodic Protection .....('43) 83
Cathodic Protection of Steel Surfaces in Contact with Water.... 67
Caulking of Pipe Joints, Pneumatic.....('44) R-109
Causes of Activated Sludge Bulking.....('43) 239
Cement Mortar Lining of Mains in Place..... 96
Centrifugal Pump Conservation.....('44) R-63
Centrifugal Pumps (see pumps).....('44) R-59
Centrifugal Pumps, Specific Speed Curves for.....('41) 22
Centrifugal Pumps, Automatic Operation of.....('43) 40
Centrifuging for Determination of Suspended Solids..... 262
Change Gear, Gauge for Meter.....('44) R-114
Channels, Rectangular, Rate of Flow in.....('43) 280
Characteristics of Natural Waters.....('43) 121
Charges for Industrial Waste, Special Sewer Service.....('44) R-166
Chart—
For Calculating Tank, Pipe and Cylinder Contents..... 270
For Determining Head Capacity, Eff., Hp..... 285
For Dry Chemical Feeders 154
For Flow in Pipe..... 40
Offset for Screwed Fittings..... 276
Hydraulic Power-Lift.....('42) 270
Chart for Determination of Pumping Costs..... 284
Chart for Determining Per Cent Sludge Digestion..... 257
Chart of Loss of Head in Feet Per 1,000 Ft. of Pipe,
.....('43) 276, ('44) R-28
Charts for Determining Equivalent Pipes and Loop Flow Distribution 83
Checking Chart for Dry Chemical Feeders..... 154
Checking Pump Efficiencies.....('44) R-59

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Checking Tuberculation by Chloramine Treatment.....('43) 169
Checking Water Hammer.....('42) 59
Check Sheet, Pump Trouble.....('43) 42
Check Valve Slam, Elimination of.....('42) 58
Chemical Analyses of Water, Interpretations of.....('43) 123
Chemical Feeders, Checking Chart for Dry..... 154
Chlor-aeration for Degreasing Sewage.....('43) 211
Chlorination—
(See Chlorine).
Control in Sewage Dosage.....('44) R-244
For Bulking Control..... 212
For Tuberculation Control.....('43) 169
Chlorine—
(See Chlorination).
And Air for Sewage Degreasing.....('43) 211
Demand 240
For Cleaning Filters..... 159
Handling 161
Ice 163
Liquid .....('41) 124
Purging of Air Diffuser Plates.....('44) R-221
Residual, Test for..... 133
Chlorine Demand Determination, The..... 240
Chlorine Dioxide Treatment of Water..... 129
Circle Areas, Table of.....('44) R-264
Circular Channels or Conduits.....Mag. 200
Circular Orifice at End of Pipe, Flow Measurement with.('44) R-103
Circular Sewers, Rate of Flow in.....('43) 281
Classified Products Index..... 2
Cleaning Air Diffuser Plates, Dry.....('43) 265
Cleaning Air Diffusion Media.....('44) R-222
Cleaning Encrusted Pipe Lines and Vacuum Filters.....('43) 248
Cleaning Filters—
With Chlorine 159
With Sulphur Dioxide.....('44) R-157
Cleaning Lime Solution Lines.....('43) 220
Cleaning Mains with Compressed Air.....Mag. 192
Cleaning, Painting, and Protecting Steel Water Tanks..... 64
Cleaning, Water Main..... 89
CO_2, Alkalinity and pH, Diagram.....('43) 286
Coagulation Aid by Colloidal Silica.....('44) Mag. 211
Coefficients, Pipe Line Friction.....('41) 59
Collecting Flocculated Samples, Apparatus for Collecting...('43) 161
Collection of Water and Sewer Accounts, Joint Administration of .....('44) R-161
Colloidal Silica as an Aid to Floc Formation.....('44) Mag. 211
Commercial Pipe Sizes for Fire Streams.....('43) 90
Compressed Air, Cleaning Mains with.....Mag. 192
Compressed Air, De-watering Mains with.....('43) 110
Compressed Air Flushing of Small Mains.....('44) R-110
Compressed Air Speeds Pipe Cutting.....('44) R-111
Compressed Air to Clear Corroded Service Lines.....('43) 113
Computing Horsepower From Revolving Watt-Hour Meters..('42) 192
Concrete Pipe, Flow Through (Chart).....('44) R-262, R-263
Concrete Pipe, Water Flow in, Nomograph.....('43) 278
Concrete Quantities, Proportioning..... 134
Concrete, Proportioning.....('44) R-160
Condition of Mains, Determining.....('44) R-101
Conical Piles, Contents of.....('44) R-250
Conservation of Centrifugal Pumps.....('44) R-63
Contents of Conical Piles.....('44) R-250
Contents of Horizontal Cylinders and Tanks..... 270
Continuous Stability Indicator, Enslow.....('42) 159
Control of Algae .....('43) 139
Control of Corrosion in Potable Water Systems.....Mag. 187
Control of Micro-Organisms and Aquatic Vegetation.....('44) R-127
Control of Odorous and Destructive Gases in Sewers and Treatment Plants 237
Control of Sewage Chlorination .....('44) R-244
Control of Sludge Bulking 212
Control of Sludge Digestion Temperature, with Live Steam..('43) 246
Control of Velocity in Grit Channels.....('44) R-169
Control of Water Quality with Calgon..... 151
Controlling Grit Chamber Velocities.....('40) 138
Control with Activated Carbon, Taste and Odor..... 125
Conversion Chart for pH .....('43) 286
Conversion Factors 265
Conversion Table, Metric .....('44) R-26
Copper and Brass Pipe, Capacity and Pressure Loss Through.... 276
Copper and Health .....('44) R-138
Copper Sulfate as an Aid to Sewer Maintenance and Sewage Treatment .....('42) 197
Copper Sulfate for Killing Roots in Sewers.....('44) R-246
Copper Sulfate, Usefulness and Application of..... 119
Correction of Water Hammer 53
Correction of Water Waste Leakage .....('44) R-105
Corrective Measures for Activated Sludge Bulking.....('43) 239
Correctives for Water Hammer.....('44) R-66, R-69
Corroded Service Line Cleaning with Compressed Air.....('43) 113
Corrosion—
Control .....Mag. 181
Effect on Copper and Health.....('44) R-138
Indicator .....('43) 170
Mechanism .....('44) R-133
Prevention 67, 148, 151
Corrosion Control in Potable Water Systems.....Mag. 187
Corrosivity Indicator .....('43) 170
Cost of Leaks, Air, Steam, Water.....('43) 282
Cost of Main, Estimating .....('42) 104
Cost of Pumping Water, Determining 101
Cost of Sludge Removal, Reducing .....('44) R-247
Costs, Pump Power: Method of Determination.....('43) 43
Cross Connections, Elimination of..... 23
Cross, The Hardy, Method.....('43) 51
Current Flow and Heat Production..... 50
Curves, Specific Speed for Centrifugal Pumps.....('41) 22
Cutting Cast Iron Pipes.....('44) R-75, R-111
Cutting Pipe, Speeded by Compressed Air.....('44) R-111
Cylinder Contents, Horizontal and Vertical..... 270
Cylindrical Tank Capacities per Foot of Depth..... 283

D

Data, Engineering 265
Decimal Equivalents .....('44) R-252
Deep Wells, Drilling and Development.....('43) 96
Defense Measures for Sewage Works.....('43) 188
Degreasing Sewage .....('43) 211
Delivery Capacity and Pressure Drop Through Copper and Brass Pipe 276
Density to Volume Ratio in Sludge.....('44) R-252
Depreciation Accounting Practices, Municipal..... 15
Depth and Flow in Circular Channels or Conduits.....Mag. 202
Depth Gauge, Warns of Intake Troubles, Recording..... 18
Design and Operation of Grease Interceptors..... 233
Design of Air Distribution Systems for Activated Sludge Plants .....('44) R-205
Design of Grit Chambers .....('41) 144
Design of Sewers, Practices of.....('44) Mag. 227
Destructive Gases in Sewers and Plants, Control of..... 237
Detection of Waste Water in Sewer Flows.....('44) R-172

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Determination of—
- Chlorine Demand 240
- Condition of Mains..... ('44) R-149
- Equivalent Pipes and Loop Flows..... 83
- Flows and Heads..... ('43) 51
- Hydrogen Sulfide 263
- Loop Flows 83
- Per Cent Sludge Digestion..... 257
- Power Costs and Pump Bids..... ('43) 43
- Residual Chlorine by O-T-A Test..... 133
- Sand in Well Water..... ('44) R-149
- Suspended Solids 262
- Sludge Solids ..... ('42) 236
- Yardage on Reels and Drums..... ('44) R-26

Determining Cost of Pumping Water..... 101

Determining Head, Capacity, Efficiency, Horsepower Chart..... 285

Determination of Pumping Costs..... 284

Developing Deep Wells, Drilling and..... ('43) 96

Development in Sludge Metering..... Mag. 198

Development of Rock Wells..... 51

De-Watering Mains with Compressed Air..... ('43) 110

Diagram, Pipe Flow 273

Diesel and Combustion Engines' Fume Trap..... ('43) 25

Diffused Air Activated Sludge Plant Operation..... ('44) R-211

Diffuser Plates—Method of Dry Cleaning..... ('43) 265

Diffuser Servicing, Porous Air ..... ('43) 266

Digestion Tank Heating, Sewage Sludge..... 215

Digestion Temperature Control with Live Steam..... ('43) 246

Discharge by Sprinkler Heads ..... ('44) R-96

Discharge Measurements, Hydrant ..... ('43) 87

Discharge Table for Parshall Flumes..... Mag. 206

Disc Meter Testing, at Correct Rate of Flows..... ('43) 117

Distribution in Loop Flows 83

Distribution System—
- Air for Activated Sludge..... ('44) R-205
- Compressed Air Flushing..... ('44) R-110
- Determining Condition of..... ('44) R-101
- Elevated Storage ..... ('44) R-91
- Emergency Repair ..... ('43) 99

Distribution System, The ..... ('44) R-79

Dosage Control in Sewage Chlorination..... ('44) R-244

Drilling and Developing Deep Wells..... ('43) 96

Drinking Water Standards, Public Health Service..... ('43) 125

Drums or Reels, Yardage on..... ('44) R-261

Dry Chemical Feeders, Checking Chart for..... 154

"Dry Cleaning" Air Diffuser Plates..... ('43) 265

E

Earth Trenching ..... Mag. 194

Economic Aspects of Water Softening..... ('43) 144

Economics of Cleaning Air Diffusion Media..... ('44) R-222

Effect of Alkalinity on pH..... ('43) 287

Efficiencies, Checking Centrifugal Pump..... ('44) R-59

Efficiency, Horsepower, Head, Capacity Chart..... 285

Effluent Analyses, Sewage and..... ('42) 250

Ejector and Washer for Grit..... ('43) 187

Electrical Calculator, A Time Saver..... ('44) R-43

Electrical Data and Horsepower 110

Electric Heat Solves Problem at Pumping Station..... ('44) R-120

Electrical Thawing ..... ('41) 70

Electricity in the Plant, Practical..... ('44) R-37

Elevated Storage ..... ('44) R-91

Elevated Tank Maintenance 61

Eliminating Surge Troubles on Pump Discharge Lines..... ('44) R-66

Elimination of Check Valve Slam..... ('42) 58

Elimination of Cross Connections in Los Angeles..... 22

Elimination of Gas Hazards at Sewage Plants..... ('42) 217

Emergency Repair of Distribution Systems..... ('43) 99

Encrusted Pipe Line, Cleaning with Acid..... ('42) 244

Encrusted Vacuum Filter, Cleaning with Acid..... ('43) 249

Engineering Data and Conversion Factors..... 261

Engine Operation on Sewage Sludge Gas..... 225

Engine Performance, Gas 229

Engines, Fume Trap for Combustion..... ('43) 25

Engines, Principles of Power Generation with Sewage Gas..('44) R-227

Enslow Continuous Stability Indicator..... ('42) 189

Entrance Losses, Hydraulic ..... ('43) 273

Equation of Pipes ..... ('44) R-261

Equilibrium, Ionic, in Water..... 156

Equipment, Maintenance of Water Works..... ('42) 109

Equipping the Sewage Plant Laboratory..... ('44) R-253

Equivalent Pipe Charts 83

Equivalents, Alkalinity 282

Equivalents, Decimals to Fractions of an Inch..... ('44) R-252

Equivalents, Heat and Power ..... ('43) 282

Equivalents of Ounces in Water and Mercury..... ('43) 282

Estimating the Cost of Mains..... ('42) 194

Examining 100 Ml. Portions of Water..... 153

Expansion Chart, of Pipe, Bar, Rail, or Beam..... ('43) 283

Experience in Diffused Air Activated Sludge Plant Operation ..... ('44) R-211

Experience in Mechanical Activated Sludge Plant Operation..... 201

Experience in Sewer Maintenance ..... ('44) R-167

Evaluation of Pump Bids by a Simple Method..... ('43) 43

F

Factors and Data 261

Feeders, Dry Chemical, Checking Chart for..... 154

Feeding Anhydrous Ammonia ..... ('41) 117

Fertilizer and Fertility ..... ('43) 261

Fertilizer, Sewage Sludge as..... 259

Ferric Chloride ..... ('44) R-247

Ferric Salts in Water and Sewage Treatment..... ('44) R-235

Fertility and Fertilizer Values of Sludge..... ('43) 261

Fertility Value of Sewage Sludge..... ('43) 264

Fertilizer, Sludge as ..... ('44) R-249

Filter Bed Maintenance ..... ('43) 155

Filters—
- Anthrafilt for 145
- Bed Maintenance ..... ('43) 155
- Cleaning with Chlorine..... 159
- Cleaning with SO_2..... ('44) R-157
- Washing ..... ('44) R-153

Financing of Sewage Works 169

Financing Sewage Works Operation ..... ('44) R-164

Fire Flows for Towns of Various Sizes..... ('43) 90

Fire Hydrant Flow Gage..... 58

Fire Protection, Water Supply in..... ('43) 73

Fire Streams, Pipe Sizes for..... ('43) 90

Fire Streams, Table of Effective..... 166

Fittings and Pipes, Loss of Head in..... ('44) R-27

Fittings, Screwed, Offset Chart for..... 276

Fixture Water Requirements 117

Flammability of Gas-Air Mixtures, Limits of..... ('43) 253

Flocculated Samples, Apparatus for Collecting..... ('43) 161

Floc Formation and Colloidal Silica..... ('44) Mag. 211

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Flow—
And Heads ..... ('43) 51
Determination ..... ('43) 51
Diagram for Pipes 273
Diagram of Sewage Processes ..... ('44) R-180-181
Fire ..... ('43) 90
Friction, Measurement & Power ..... ('44) R-17
Gage for Sewers, Maximum ..... ('44) R-193
Gage, Hydrant 50
Hydrant Gage ..... 50, ('43) 87
In Circular Sewers ..... ('43) 281
In Concrete Pipes ..... ('44) R-262-263, ('43) 278
In Copper & Brass Pipes 276
In House Service Pipes ..... ('44) R-96
In Loops 83
In Pipes 40
In Rectangular Channels ..... ('43) 280
Loss of Head ..... ('44) R-27
Mannings Formula for 279
Measurements by Orifice ..... ('43) 38-39
Measurement in Conduits ..... Mag. 206
Measurement in Open Channels 191
Parshall Flume for ..... Mag. 206
Through Water Pipes 274
Flow and Depth in Circular Channels or Conduits ..... Mag. 200
Flow in Rectangular Channels ..... ('43) 280
Flow Measurement by the Orifice Method ..... ('43) 38, 39
Flow Measurement with the Circular Orifice at the End of Pipe ..... ('44) R-103
Flow of Water in House Service Pipes ..... ('43) 114
Flow Powergraph 272
Flume, Parshall, for Grit Chambers ..... ('40) 138
Flushing of Small Mains with Compressed Air ..... ('44) R-110
Flushing Sewers ..... ('44) R-192
Forestation ..... Mag. 181
Formation of Floc with Colloidal Silica ..... ('44) Mag. 211
Free-Flow Discharge Table for Parshall Measuring Flumes .. Mag. 206
Friction Coefficients, Pipe Line ..... ('41) 59
Friction Loss—
Condition of Mains ..... (44) R-101
In Pipes, Valves & Fittings ..... ('44) R-27
Friction Measurement and Power, Flow ..... ('44) R-17
Frost, Protecting Water Pipes from ..... ('41) 74
Fume Trap for Combustion Engines ..... ('43) 25
Fundamentals of the Activated Sludge Process 197

G

Gage, Hydrant Flow 50
Gage for Sewers, Maximum Flow ..... ('44) R-193
Gallons in Water Supply Pipe (Nomograph) ..... ('42) 274
Gas-Air Mixtures, Limits of Flammability ..... ('43) 258
Gas Engine Operation on Sewage Sludge Gas 225
Gas Engine Performance 229
Gas Engines, Principles of Power Generation with Sewage. ('44) R-227
Gas Engine Installation 228
Gases in Sewers and Plants, Control of 237
Gas Hazards ..... ('43) 256
Gas Hazards at Sewage Plants ..... ('42) 217
Gasoline—Use in "Dry Cleaning" Diffuser Plates ..... ('43) 265
Gate Valve Care and Maintenance 105
Gauge for Meter Change Gears ..... ('44) R-114
Gauge, Warns of Intake Troubles, Recording Depth 18
Gear Gauge, Change, for Meter ..... ('44) R-114
Grease Interceptors, Design and Operation of 233
Grinding Sewage Screenings ..... ('43) 194
Grit Chamber Design ..... ('41) 144
Grit Chamber Velocities, Controlling ..... ('40) 138
Grit Channel, Velocity Control ..... ('44) R-169
Grit Removal ..... ('41) 144
Grit Washer and Ejector, Pneumatic ..... ('43) 187

H

Hammer, Water ..... ('44) R-69, 53
Handling, Anhydrous Ammonia ..... ('41) 117
Handling Chlorine, Practical Aspects of 161
Handling Sewage Sludge Problems 245
Hardness, Removal of Iron and ..... ('44) R-141
Hard Spot and Mud-Ball Breaker ..... ('44) R-143
Hardy Cross Method ..... ('43) 51
Hazards at Sewage Plants, Gas ..... ('42) 217
Hazards, Gas ..... ('43) 256
Head, Capacity, Efficiency, Horsepower Chart 285
Head Losses, Hydraulic Entrance ..... ('43) 279
Head Loss in Pipe, Chart ..... ('43), 276, ('44) R-28
Head Loss in Pipes and Fittings ..... ('44) R-27
Heads and Flows in Pipe Systems (Hardy Cross Method) .... ('43) 51
Health and Copper ..... ('44) R-138
Heat and Power Equivalents ..... ('43) 282
Heat Production and Current Flow 50
Heating Sludge Digestion Tanks 215
Horizontal Cylinders and Tanks, Contents of 270
Horsepower and Electrical Data 110
Horsepower from Revolving Watt-Hour Meters, Computing .. ('42) 192
Horsepower, Head, Capacity, Efficiency Chart 285
Hourly Load Variations in Sewage Plant Operation ..... ('43) 235
House Service Pipe Flow ..... ('44) R-96
How to Bend Pipes ..... ('44) R-111
How to Compare Pump Efficiencies 52
Hydrant Discharge Measurements ..... ('43) 87
Hydrant Flow Gage 116
Hydrant Maintenance 107
Hydraulic Entrance Losses ..... ('43) 279
Hydraulic Power-Lift Chart ..... ('42) 270
Hydraulics, Practical 43
Hydrogen Sulfide Determination 263

I

I-Beam Loadings 281
Importance of Testing Disc Meters at the Correct Rates of Flow ..... ('43) 117
Improved Method for Rating Wells 47
Improved Method of Making Wet Taps ..... ('43) 110
Improved Method of Velocity Control in Grit Channels .... ('44) R-169
Improved Residual Chlorine Test 133
Improving Operation of a Small Sewage Plant ..... ('43) 217
Incineration of Sludge ..... ('44) R-253
Incrustation in Lime Solution Lines, How to Retard ..... ('43) 220
Incrusted Wells, Treatment ..... ('43) 98
Index of Classified Products 2
Index Test, Sludge ..... ('44) Mag. 222
Indicator, Enslow Continuous Stability ..... ('42) 159
Indicator of Corrosivity ..... ('43) 170
Industrial Wastes—
Sewer Service Charges for ..... ('44) R-166

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Information on Water and Sewage Works Problems—
A list of Books, Handbooks and Journals ..... ('44) R-15
Inhibited Muriatic Acid, for Cleaning..... ('43) 248
Inlet and Manhole Traps for Sewer Odors..... ('44) R-195
Instructive Wall Panel for Treatment Plants..... ('44) R-248
Intake Troubles, Recording Depth Gauge, Warns of..... 50
Interceptors, Grease, Design and Operation..... 233
Internal Combustion Engine Fume Trap..... ('43) 25
Interpretation of Chemical Analyses of Water..... ('43) 123
Interpretation of Sewage Analyses ..... ('42) 250
Ionic Equilibrium in Water..... 156
Iron and Hardness, Removal of..... ('44) R-141
Iron Removal—Small Systems 141

J

Joint Administration and Collection of Water and Sewer Accounts ..... ('44) R-161
Joint Caulking, Pneumatic ..... ('44) R-109
Jointing, Proper Sewer ..... ('44) R-194

K

Keeping Filters Clean with Chlorine 159
Keeping Lime Solution Lines Clean ..... ('43) 220
Killing Roots in Sewers with Copper Sulphate..... ('44) R-246
Kinks, Some Sewerage Operating..... 181

L

Laboratory Equipment for Sewage Plants..... ('44) R-255
Land Measures ..... ('44) R-55
Land Owner, Problems of a Municipal Water Works..... Mag. 181
Leak Costs, Air, Steam, Water..... ('43) 282
Leak Costs 108
Legal Responsibilities of Water Operators..... ('43) 23
Levelling and Aligning Method..... 46
Lime and Lime Slaking 139
Lime Solution Lines, How to Keep Clean..... ('43) 220
Limits of Flammability of Gas-Air Mixtures..... ('43) 258
Lining Cast Iron Mains in Place with Cement Mortar..... 96
Liquid Chlorine ..... ('41) 124
Literature on Water Works and Sewerage—
Representative List of Books, Handbooks, Journals, etc. ('44) R-15
Loading for I-Beams, Safe 281
Loading for Wooden Beams, Safe..... 280
Log, Operating, for Small Sewage Plant..... ('43) 236
Logs for Small Water Plants, Operating..... 152
Loop Flow Distribution Charts..... 83
Los Angeles, Elimination of Cross Connections in..... 23
Losses, Hydraulic Entrance..... ('43) 279
Loss of Head in Pipes and Fittings ..... ('44) R-27
Loss of Head in Pipe Chart ..... ('43), 276, ('44) R-28

M

Main and Service Line Thawing..... ('41) 70
Main Cleaning, Water ..... Mag. 192, 89
Main Cleaning with Compressed Air..... Mag. 192
Main Line Metering of Water, Sewage and Sludge..... 34
Main Line Meters, Selection of..... ('44) R-45
Mains, Determining the Condition of..... ('44) R-101
Mains, Dewatering of, with Compressed Air..... ('43) 110
Mains, Lining with Cement Mortar, in Place..... 96
Maintenance—
Bottoms of Filters..... ('43) 159
Centrifugal Pumps ..... ('44) R-59, R-63
Filter Bed ..... ('43) 96
Gate Valves 105
Hydrant 107
Pumping Station ..... ('44) R-199
Sewer ..... ('42) 197, ('43) 177, ('44) R-197
Sewer 177
Tanks ..... ('43) 80 ('44) R-91
Tanks 61
Water Well Capacity..... ('44) R-112
Water Works Equipment..... ('42) 199
Maintenance of Elevated Tanks 61
Maintenance of Sewage Pumping Stations 253
Maintenance of Tanks and Standpipes ..... ('42) 69
Maintenance of Water Well Capacity ..... ('44) R-112
Making Pipe Bushings from Standard Pipe..... 61
Management Problems in Municipal Water Works..... ('43) 21
Manganese Removal ..... ('44) R-147
Manhole and Inlet Traps for Sewer Odors..... ('44) R-195
Manning's Formula Nomograph 270
Manual of Water Sanitation Practice..... ('43) 121
Materials, Weights of..... ('44) R-81
Maximum Flow Gage for Sewers..... ('44) R-199
Measurement and Power, Flow, Friction..... ('44) R-17
Measurement of Flow in Circular Channels and Conduits..... Mag. 202
Measurement of Flow in Open Channels..... 191
Measurements, Hydrant Discharge ..... ('43) 87
Measures and Weights 270
Measures of Land ..... ('44) R-55
Measuring Flows by the Orifice Method..... ('43) 38
Mechanical Activated Sludge Plant Operation, Experience in..... 283
Mechanism of Corrosion of Water Pipes, The..... ('44) R-133
Mercury and Water, Equivalents of Ounces in..... ('43) 282
Media for Air Diffusion, Economics of Cleaning..... ('44) R-222
Metering of Water, Sewage and Sludge, Main Line..... 34
Metering, Practical Methods of Procedure..... ('44) R-115
Meters—
Change Gear Gage..... ('44) R-114
Computing Hp. from..... ('42) 192
Main Line 34
Main Line, Selection of..... ('44) R-45
Propeller Type 37
Renovating ..... ('43) 116
Selection ..... ('43) 119
Shop for ..... ('44) R-118
Sludge ..... Mag. 196
Testing ..... ('43) 116, ('43) 117
Meter Testing, Disc, at Correct Rates of Flow..... ('42) 117
Method for Determining Hydrogen Sulfide 263
Method for Determining Sludge Solids..... ('42) 236
Method of Making Wet Taps, Improved..... ('43) 110
Method of Velocity Control in Grit Channels..... ('44) R-169
Methods of Procedure for Metering..... ('44) R-115
Method for Rating and Sampling Wells..... 47
Metric Conversion Table ..... ('44) R-26
Micro-organisms and Aquatic Vegetation, Control of..... ('44) R-127
Modern Financing of Sewage Works..... 169
Mud-Ball and Hard Spot Breaker..... ('44) R-143
Mud Hog, The 116
Municipal Depreciation Accounting Practices 15
Municipal Water Works Land Owner, Problems of..... Mag. 181
Municipal Water Works Management, Problems in..... ('43) 21

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

N

Natural Waters, Characteristics of.....('43)121
New Development in Sludge Metering.....Mag. 198
Nomograph for Solving Manning's Formula..... 278
Nomograph for Water Pipe Flow..... 274
Nomographic Chart for Flow in Pipes..... 40
Numbers, Roots and Powers of (Nomograph).....('42) 278

O

Odor Control with Activated Carbon..... 125
Odors and Gases in Sewers and Plants, Control of..... 237
Odor Traps for Sewer Manholes and Inlets.....('44) R-195
Offset Chart for Screwed Fittings..... 276
Open Channel Flow Measurement by Parshall Flume..... 191
Operating Engines on Sewage Sludge Gas..... 225
Operating Fundamentals of the Activated Sludge Process..... 197
Operating Kinks, Sewerage 181
Operating Log for a Small Sewage Plant.....('43) 236
Operating Logs for Small Water Plants..... 152
Operation and Maintenance of Small Pumping Stations...('44) R-199
Operation of Activated Sludge Plants .....('44) R-211
Operation of Centrifugal Pumps, Automatic.....('43) 40
Operation of Grease Interceptors 233
Operation of Sewage Treatment Plants..... 187
Operation of a Small Sewage Treatment Plant.....('43) 217
Operation, Sewage Plant, and Hourly Load Variation.....('43) 235
Operators' Legal Responsibilities, Water.....('43) 23
Orifice at End of Pipe, Flow Measurement with.....('44) R-103
Orifice Method for Measuring Flows.....('43) 38
Orifice Table for Determining Water Flow.....('43) 39
Ortho-Tolidine-Arsenite (OTA) Test for Residual Chlorine..... 133
Oxidants and Reductants in Sewage Plant Effluents and Streams 211

P

Packing Pointers .....('44) R-204
Painting and Protecting Steel Water Tanks..... 64
Painting Damp Water Pipes.....('44) R-154
Panel, Wall, for Treatment Plants.....('44) R-248
Parshall Flume for Grit Chambers .....('40) 128
Parshall Flume for Open Channel Flow Measurement..Mag. 206, 191
Per Cent Sludge Digestion, Chart for Determining..... 257
Performance, Gas Engine 229
pH, Alkalinity and CO_2, Diagram.....('43) 286
pH Conversion Chart.....('43) 286
pH Relation to Alkalinity.....('43) 287
pH Zones in Water and Sewage Treatment.....('43) 285
Pipe—
Bending .....('44) R-96
Bushings 63
Concrete, Flow in.....('44) R-262 & 263
Corrosion Mechanism .....('44) R-133
Cutting by Compressed Air.....('44) R-111
Cutting Cast Iron.....('44) R-75
Encrustation, Cleaning of.....('43) 248
Equations .....('44) R-261
Expansion .....('43) 283
Flow in House Service.....('44) R-96
Flow in Loops..... 83
Flow, Nomograph for..... 40
Flow, Scobey Formula.....('43) 278
Joint Caulking .....('44) R-109
Line Carrying Capacity..... 266
Line Contents, Calculation of..... 270
Line Friction Coefficients.....('41) 59
Line Surge of Pump Discharge.....('44) R-66
Loss of Head Chart.....('43) 276, ('44) R-28
Loss of Head in.....('44) R-27
Materials .....('44) Mag. 216
Orifice .....('44) R-103
Painting Damp .....('44) R-154
Protection from Frost.....('41) 74
Sizes for Fire Streams.....('43) 90
Sweating 131
System .....('43) 51
Water Flow Through..... 274
Within Buildings, Regulating..... 19
Velocity In. .....('43) 277, ('44) R-31
Volume .....('42) 274
Pipe Flow Diagram 273
Pipes and Fittings, Loss of Head in.....('44) R-27
Pipe Line Friction Coefficients.....('41) 59
Pipe System, Flows and Heads (Hardy Cross Method).....('43) 51
Piping Within Buildings, Regulating Water..... 19
Plan for Sewage Works Operation, Financing, Revenue....('44) R-164
Plants, Operating Logs for Small Water..... 152
Plant Operation, Improving Small Sewage Treatment.....('43) 217
Plant Operation, Sewage Treatment 187
Plates, Air Diffuser, Purging with Chlorine.....('44) R-221
Plate Gauges 105
Plus Values of Sewage Sludges—Fertility.....('43) 264
Pneumatic Caulking of Pipe Joints.....('44) R-109
Pneumatic Grit Washer and Ejector.....('43) 187
Porous Air Diffuser Servicing.....('43) 266
Porous Plate Filter Bottoms, Practical Aspects of.....('43) 159
Potable Water Systems, Corrosion Control in.....Mag. 187
Pounding, Pump, Corrected by Air Sniffer.....('42) 74
Power and Heat Equivalents.....('43) 282
Power Costs, in Evaluating Pump Bids.....('43) 43
Power Crane Truck .....('44) R-36
Power, Flow, Friction, Measurement, and.....('44) R-17
Power Generation with Sewage Gas Engines.....('44) R-227
Powergraph, Flow 272
Power-Lift Chart, Hydraulic.....('42) 270
Powers and Roots of Numbers (Nomograph).....('42) 278
Practical Aspects of Handling Chlorine..... 161
Practical Aspects of Porous Plate Filter Bottoms.....('43) 159
Practical Electricity in the Plant.....('44) R-37
Practical Hydraulics 43
Practical Methods of Metering.....('44) R-115
Practice, Manual of Water Sanitation.....('43) 128
Practice of Water Meter Testing.....('43) 116
Practice, Trenching .....Mag. 194
Practices in Municipal Depreciation Accounting..... 15
Practices, Sewer Design .....('44) Mag. 227
Pressure Drop Through Brass and Copper Pipe..... 276
Pressure, Water—Head to Pounds..... 283
Preventing Corrosion by Water Treatment..... 148
Principles and Practice of Water Meter Testing.....('43) 116
Principles of Power Generation with Sewage Gas Engines.('44) R-227
Problem of Chlorine Ice..... 163
Problems in Handling Sewage Sludge..... 245
Problems in Municipal Water Works Management.....('43) 21
Problems of a Municipal Water Works Land Owner.....Mag. 181
Process, Activated Sludge 197

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Processes and Results, Sewage Treatment.....('44) R-175
Products, Classified Index of..... 2
Propeller-Type Meters 37
Proper Sewer Jointing .....('44) R-194
Properties of Chlorine .....('41) 124
Proportioning Concrete .....('44) R-160
Protecting Steel Water Tanks 64
Protecting Water Pipes from Frost.....('41) 74
Protection, Cathodic .....('43) 83
Protection, Cathodic, of Steel Surfaces in Contact with Water.... 67
Public Health Service Drinking Water Standards.....('43) 125
Public Relations and Water Leak Costs.....('43) 282
Pumping Costs, Chart for Determination of..... 284
Pumping Problem, Air Release Solves..... 256
Pumping Sewage and Sludge..... 249
Pumping Sludge .....('43) 231
Pumping Station, Electric Heat Solves Problems at.....('44) R-120
Pumping Station Operation and Maintenance.....('44) R-199
Pumping Stations, Maintenance of Sewage..... 253
Pump Pounding Corrected by Simple Air Sniffer.....('42) 74
Pumps—
Bid Evaluation .....('43) 43
Capacity, Reciprocating .....('42) 274
Centrifugal .....('43) 40, ('44) R-59
Conservation of .....('44) R-63
Discharge Line Surge.....('44) R-66
Efficiencies .....('44) R-59
Efficiencies 52
Maintenance .....('44) R-63
Packing Pointers .....('44) R-204
Pounding .....('42) 74
Specific Speed Curves for.....('41) 22
Terminology .....('44) R-62
Trouble Check Sheet.....('43) 42
Pump Trouble Check Sheet.....('43) 42
Purging Air Diffuser Plates with Chlorine.....('44) R-221

Q

Quality of Water Control with Calgon..... 151

R

Rapid Method for Determining Sludge Solids.....('42) 236
Rate, or Velocity, of Flow in Circular Pipes.....('43) 281
Rate, or Velocity of Flow in Rectangular Channels.....('43) 280
Rates of Flow for Various Uses and Fixtures..... 117
Rating and Sampling Wells by an Improved Method..... 47
Ratio of Sludge Density to Volume.....('44) R-252
Reciprocating Pumps, Capacity of (Nomograph).....('42) 274
Recording Depth Gauge, Warns of Intake Troubles..... 18
Rectangular Channels, Rate of Flow in.....('43) 280
Reducing Cost of Sludge Removal.....('44) R-247
Reductants and Oxidants in Sewage Plant Effluents and Streams.. 211
Reduction of Gas Hazards in Sewage Plants.....('43) 256
Reels or Drums, Yardage on.....('44) R-261
Reforestation .....Mag. 181
Regulating Water Piping Within Buildings..... 19
Relative Carrying Capacities of Pipe Lines of Equal Smoothness. 266
Relative Sizes of Branches and Water Mains.....('43) 282
Removal of Grit .....('41) 144
Removal of Iron and Hardness.....('44) R-141
Removal of Iron in Small Systems..... 141
Removal of Manganese .....('44) R-147
Removal of Sand from Well Water.....('42) 114
Removal of Sludge, Reducing Cost of.....('44) R-247
Renovating Water Meters .....('44) 116
Repainting Steel Water Tanks.....('44) R-91
Repair of Distribution Systems, Emergency.....('43) 91
Requirements for Paints on Water Tanks.....('44) Mag. 207
Requirements, Water 117
Residual Chlorine, Ortho-Tolidine-Arsenite Test for..... 132
Responsibilities, Legal, of Water Operators.....('43) 22
Revenue Plan for Sewage Works Financing.....('44) R-164
Revolving Watt-Hour Meters, Computing Horsepower from..('42) 192
Rock Trenching .....Mag. 194
Rock Well Development..... 51
Roots and Powers of Numbers (Nomograph).....('42) 273
Roots in Sewers, Killing.....('44) R-246

S

Safe Loading for I-Beams..... 281
Safe Loading for Wooden Beams..... 280
Sampling and Rating Wells..... 47
Sand in Well Water, Determination of.....('44) R-140
Sand Removal from Well Water.....('42) 114
Sanitation Practice, Manual of Water.....('43) 123
Scobey Formula for Flow of Water in Concrete Pipe.....('43) 278
Screenings, Sewage, Trituration of.....('43) 194
Screwed Fittings, Offset Chart for..... 276
Selecting the Right Meter.....('43) 119
Selection of Centrifugal Pumps .....('44) R-59
Selection of Main Line Meters.....('44) R-45
Self Cleaning Strainers for Sand Removal.....('42) 114
Service and Maintenance of Sewers..... 177
Service Charges for Industrial Waste, Special Sewer.....('44) R-166
Service Lines and Main Thawing.....('41) 70
Service Lines, Blowing Out .....('43) 112
Service Pipes, Flow in House.....('44) R-96
Service Shooting .....('43) 113
Service, Standards for Water 111
Servicing of Porous Air Diffusers.....('43) 266
Sewage—
Chlorine Dosage Control.....('44) R-244
Collection of Joint Accounts.....('44) R-161
Degreasing .....('43) 211
Gas Engines .....('44) R-227
Gas Engines 225, 229
Gas Hazards .....('43) 256
Laboratory Equipment .....('44) R-255
Load Variations .....('43) 235
Metering 34
Operators Slide Rule.....('44) R-184
Oxidants and Reductants..... 211
Plant Effluents 211
Plant Operating Log.....('43) 236
Plant Operation .....('43) 235
Plant Operation 187
Pump Air Release..... 256
Pumping Station Maintenance..... 253
Sludge Fertility .....('43) 256
Sludge Gas Engines.....225, 229
Sludge Handling 245
Screenings Trituration .....('43) 194
Works Defense Measures.....('43) 188
Works Operation Financing.....('44) R-164
Sewage and Effluent Analyses .....('42) 260
Sewage and Sludge Pumping 249
Sewage and Water Works Problems, Information on.....('44) R-15
Sewage Sludge as Fertilizer..... 259
Sewage Sludge Digestion Tank Heating..... 215

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Sewage Treatment—
Cleaning Diffuser Media ('44) R-222
Ferric Chloride Coagulation ('44) R-235
Gas Hazards ('42) 217
Plant Laboratory ('44) R-255
Plant Operation 187
Plant Operation ('42) 217, ('43) 235
Plant Operation Financing ('44) R-164
Plant Operation Log ('43) 236
Processes and Results ('44) R-175
Wall Panel Chart ('44) R-248
Sewage Treatment Aided by Copper Sulfate ('42) 197
Sewage Treatment, Plant Operation 187
Sewage Treatment Processes and Results ('44) R-175
Sewage Works Financing 169
Sewer—
Collection of Joint Accounts ('44) R-161
Flow Detection of Waste Water ('44) R-172
Flow Gage, Maximum ('44) R-193
Flushing ('44) R-192
Jointing ('44) R-194
Maintenance ('44) R-187
Odor Control 237
Odor Traps ('44) 195
Rate of Flow in ('43) 281
Rental 169
Service Charges for Industrial Waste ('44) R-166
Size and Slope ('44) R-204
Sewerage Operating Kinks 181
Sewer Design Practices ('44) Mag. 227
Sewer Maintenance ('43) 177
Sewer Maintenance Aided by Copper Sulfate ('42) 197
Sewer Rents, Water Service and (Court Decision) ('43) 233
Sewer Service and Maintenance 177
Sheet Gauges 105
Shop, A Small Meter ('44) R-118
Significance, Anthrafilt and Its 145
Significance of Sewage Analyses ('42) 250
Silica and Floc Formation, Colloidal ('44) Mag. 211
Simple Air Sniffer to Correct Pump Pounding ('42) 74
Simplified Transportation ('44) R-36
Size and Slope of Sewers ('44) R-168
Slaking Lime 139
Slide Rule for Sewage Operators ('44) R-184
Slope and Size of Sewers ('44) R-168
Sludge—
As Fertilizer 259
Bulking, Activated 212, ('42) 203, ('43) 239
Cost of Removal ('44) 247
Density—Volume Ratios ('44) R-252
Digestion Tank Heating 215
Fertilizer 259
Fertilizer ('43) 261, ('43) 264, ('44) R-279
Gas Engines ('44) R-206
Gas Engine Operation 225, 229
Handling Problems 245
Incineration ('44) R-253
Metering Mag. 198, 34
Pumping ('43) 231
Solids Determination ('42) 236
Thickening ('42) 243
Sludge as Fertilizer ('44) R-249
Sludge Bulking Controlled by Chlorination 212
Sludge Digestion Temperature Control (Live Steam) ('43) 246
Sludge Gas Engine Installations in U. S. 228
Sludge Index Test in Activated Sludge Operation ('44) Mag. 222
Sludge Pumping, and Sewage 249
Sludge Triangle Procedure ('42) 236
Small Meter Shop, A ('44) R-118
Small Pumping Station Operation and Maintenance ('44) R-199
Small Systems, Iron Removal in 141
Small Water Plants, Operating Logs for 152
Sniffer, Air, Corrects Pump Pounding ('42) 74
Softening Water, Economic Aspects of ('43) 144
Solids, Determination of Sludge ('42) 236
Solids, Suspended, Determination of 262
Solving a Sewage Pumping Problem 256
Solving Chlorine Ice Problems 163
Solving Manning's Formula, Nomograph for 278
Some Practical Aspects of Handling Chlorine 161
Some Relationships Between Current Flow and Heat Production 50
Some Sewerage Operating Kinks 181
Spacing and Submergence of Suction Bells ('41) 25
Special Sewer Service Charges for Industrial Wastes ('44) R-166
Specific Speed Curves for Centrifugal Pumps ('41) 22
Speed Curves, Specific, for Centrifugal Pumps ('41) 22
Sprinkler Head Discharge ('44) R-96
Squares, and Square Roots, Table of ('44) R-264
Stability Indicator, Enslow Continuous ('42) 159
Standard Gauges 105
Standards for Drinking Water, USPHS ('43) 125
Standards for Water Service 111
Standpipes and Tanks, Maintenance of ('42) 89
Station Operation and Maintenance, Small Pumping ('44) R-199
Stations, Maintenance of Sewage Pumping 253
Storage, Elevated ('44) R-91
Storage, Feeding and Handling Ammonia ('41) 117
Steam for Control of Sludge Digestion Temperature ('43) 246
Steam Leak Costs ('43) 282
Steel Surfaces, Cathodic Protection of 67
Steel Water Tanks, Cleaning, Painting, Protecting 64, 67
Strainers for Sand Removal from Well Water ('42) 114
Study and Correction of Water Hammer 53
Sub-Aqueous Trencher, Air-Lift 116
Submergence and Spacing of Suction Bells ('41) 25
Suction Bells, Submergence and Spacing of ('41) 25
Sulphate, Copper 119
Sulphur Dioxide for Filter Cleaning ('44) R-157
Surfaces, Areas, Volumes, Calculation of 267
Surge Troubles on Pump Discharge Lines, Eliminating ('44) R-66
Surveys and Leakage Correction, Water Waste ('44) R-105
Suspended Solids, Determination of, by Centrifuging 262
System, Distribution ('44) R-79
Systems, Small—Iron Removal in 141

T

Table of Effective Fire Streams 108
Tank Maintenance ('42) 80
Tanks—
Capacity per Ft. Depth 283
Cathodic Protection of 67
Cleaning, Painting, Protecting 64, 67
Contents—Horizontal and Vertical 270
Elevated 61
Elevated ('44) R-91
Heating of Sludge Digestion 215
Maintenance 61
Maintenance ('42) 89, ('43) 80
Taps, Wet, Improved Method of Making ('43) 110
Taste and Odor Control with Activated Carbon 125
Temperature Control, Digestion (With Live Steam) ('43) 246
Terminology in Pumping ('44) R-62
Test for Residual Chlorine, O-T-A 133
Testing Disc Meters at Correct Rates of Flow ('43) 117
Testing Water Meters, Principle and Practice ('43) 116
Thawing of Service Lines and Mains, Electrical ('41) 70
Theoretical Horsepower 283
Thickening, Activated Sludge ('43) 243
Those Plus Values of Sewage Sludges ('43) 264
Time Saving Calculator ('44) R-43
To Stop Pipe Sweating 131
Treating Incrusted Wells ('43) 98

REFERENCE AND DATA INDEX — 1941 through 1945

All subjects in the previous issues are listed with the respective key,—('41), ('42), ('43), or ('44)

Treating Water to Prevent Corrosion 148
Treatment of Water with Calgon 151
Treatment of Water with Chlorine Dioxide 129
Treatment Plant Operation, and Hourly Load Variation ..... ('43) 235
Treatment Plant Operation, Improving Small Sewage ..... ('43) 217
Treatment Plant Operation, Sewage 187
Treatment Processes and Results, Sewage ..... ('44) R-175
Treatment with Chloramine to Check Tuberculation ..... ('43) 169
Traps for Odors from Sewer Manholes and Inlets ..... ('44) R-195
Transportation Simplified ..... ('44) R-36
Trencher, Sub-aqueous Air-Lift 116
Trenching Practice ..... Mag. 194
Triangle Procedure, Sludge ..... ('42) 236
Trituration of Sewage Screenings ..... ('43) 194
Trouble Check Sheet, Pump ..... ('43) 42
Truck, Power Crane ..... ('44) R-36
Tuberculation Checking by Chloramine ..... ('43) 169

U

Unbilled Revenue and Accounted for Water 109
Underwriters, National Board, Fire Flow Table ..... ('43) 90
Usefulness of Copper Sulfate 119

V

Vacuum Filter Encrustation, Cleaning with Acid ..... ('43) 248
Values of Sewage Sludge, Fertilizer and Fertility ..... ('43) 261
Value of Sewage Sludge, Fertility ..... ('43) 264
Valve Care and Maintenance, Gate 105
Valve Slam, Elimination of Check ..... ('42) 58
Variations in Hourly Load, and Sewage Plant Operation ..... ('43) 235
Velocities, Controlling Grit Chamber ..... ('40) 138
Velocity Control in Grit Channels ..... ('44) R-169
Velocity in Pipes ..... ('43) 277, ('44) R-31
Velocity or Rate, of Flow in Circular Pipes ..... ('43) 281
Velocity or Rate, of Flow in Rectangular Channels ..... ('43) 280
Vertical Cylinder and Tank Contents 270
Volume Demand and Rates of Flow for Various Uses and Fixtures 117
Volumes, Surfaces, Areas, Calculation of 267
Volume to Density Ratio in Sludge ..... ('44) R-252

W

Wall Panel for Treatment Plants ..... ('44) R-248
Washer and Ejector for Grit ..... ('43) 187
Washing Filters ..... ('44) R-151
Waste Oil from Sewers, Exclusion of ..... ('44) Mag. 226
Waste Surveys and Leakage Correction, Water ..... ('44) R-105
Waste Water Detection in Sewer Flows ..... ('44) R-172
Water—
Accounted for, and Unbilled Revenue 109
Analysis ..... ('43) 123
And Sewer Joint Accounts ..... ('44) R-161
Aquatic Vegetation Control ..... ('44) R-127
Characteristics, Natural ..... ('43) 121
Chloramine for Tuberculation Checking ..... ('43) 169
Coagulation with Ferric Salts ..... ('44) R-235
Corrosion Control ..... Mag. 187
Corrosivity Indicator ..... ('43) 116
Examination 155
Ferric Salts in ..... ('44) R-235
Flow in Concrete Pipe ..... ('43) 128
Flow in House Services ..... ('43) 114
Flow Through Pipes 274
Hammer 53
Hammer ..... ('42) 59, ('44) R-66 & R-69
Head Loss ..... ('44) R-27
Ionic Equilibrium in ..... [illegible]
Iron and Hardness Removal ..... ('44) R-14[illegible]
Iron Removal ..... [illegible]
Leak Costs ..... [illegible]
Main Condition ..... ('44) R-[illegible]
Mains & Branches, Sizes of ..... ('43) [illegible]
Manganese Removal ..... ('44) R-[illegible]
Metering, Main Line ..... [illegible]
Meter Renovation ..... ('43) [illegible]
Operator's Legal Responsibilities ..... ('43) [illegible]
Pipe Corrosion Mechanism ..... ('44) R-[illegible]
Pipe Frost Protection ..... ('41) [illegible]
Piping Within Buildings ..... [illegible]
Plant Operating Logs ..... [illegible]
Pumping Costs ..... [illegible]
Quality Control ..... [illegible]
Sanitation Practice ..... ('43) [illegible]
Service Standards ..... [illegible]
Standards ..... ('43) [illegible]
Systems, Corrosion Control in ..... Mag. [illegible]
Velocity in Pipes ..... ('43) 277, ('44) R-[illegible]
Waste Detection ..... ('44) R-[illegible]
Waste Leakage ..... ('44) R-[illegible]
Well Capacity Maintenance ..... ('44) R-[illegible]
Water and Sewage Treatment, Ferric Salts in ..... ('44) R-[illegible]
Water and Sewage Works Problems, Information on ..... ('44) R-[illegible]
Water Examination, 100 Ml. Portions ..... [illegible]
Water Flow in House Service Pipes ..... ('43) [illegible]
Water Flow Through Pipes ..... [illegible]
Water Hammer ..... ('44) R-69, [illegible]
Water Leak Costs ..... ('43) [illegible]
Water Main Cleaning ..... [illegible]
Water Meter Testing, Principle and Practice ..... ('43) [illegible]
Water Pressure—Head to Pounds ..... [illegible]
Water Requirements ..... [illegible]
Water Service and Sewer Rents ..... ('43) [illegible]
Water Service Standards ..... [illegible]
Water Softening ..... ('43) [illegible]
Water Supply in Fire Protection ..... ('43) [illegible]
Water Supply Pipe, Gallons in (Nomograph) ..... ('42) [illegible]
Water Tank Protection, Cathodic ..... ('43) [illegible]
Water Tanks, Cleaning, Painting and Protecting Steel ..... [illegible]
Water Works Equipment, Maintenance of ..... ('42) [illegible]
Water Works Land Owner, Problems of a Municipal ..... Mag. [illegible]
Water Works Management, Problem in Municipal ..... ('43) [illegible]
Watt-Hour Meters, Computing Horsepower from Revolving ..... ('42) [illegible]
Weights and Measures ..... [illegible]
Weights of Materials ..... ('44) R-[illegible]
Well Capacity, Maintenance of Water ..... ('44) R-[illegible]
Wells—
Development of Rock ..... [illegible]
Drilling and Developing ..... ('43) [illegible]
Rating and Sampling ..... [illegible]
Treating Incrusted ..... ('43) [illegible]
Well Water, Removal of Sand from ..... ('42) [illegible]
Well Water Sand, Determination of ..... ('44) R-[illegible]
Wet Taps, Improved Method of Making ..... ('43) [illegible]
What Leaks Cost ..... ('43) [illegible]
Where the Water Dollar Goes ..... [illegible]
Wire Gauges ..... [illegible]
Wooden Beams, Safe Loading for ..... [illegible]

Y

Yardage on Reels or Drums, Determining ..... ('44) R-[illegible]

Z

Zones of pH in Water and Sewage Treatment ..... ('43) [illegible]

AUTHOR INDEX — REFERENCE AND DATA SECTION
1941 through 1945

A

Ackerman, Walter J. ('43) 169
Albert, Paul McH. Mag. 200, 278
Amsbary, Frank C., Jr. ('41) 70
Anderson, C. George ('43) 177
A. W. W. A. Committee ('44) R-95
A. W. W. A. Committee 240

B

Backmeyer, David 229
Banta, A. P. 187
Barker, Stanley T. ('40) 138
Baylis, John R. 148
Beckwith, H. E. ('44) R-59
Bennett, Richard ('44) R-69
Bennett, Richard Mag. 194
Bingham, Chris F. 161
Bloodgood, Don E. ('44) Mag. 222
Brossman, Chas. ('44) R-91
Brown, R. F. ('44) R-110
Brown, Thomas and Preston, George 225
Bunker, George C. ('44) R-149
Burr, Francis K. ('44) R-235
Bushee, Ralph J. ('44) R-169

C

Calderwood, Don C. ('43) 25
Calderwood, Don C. ('44) R-114
Calderwood, Don C. 163
Carr, Arthur J. ('43) 96
Carr, Arthur J. 51
Carr, Ralph L. (See Quinn, R. J.)
Clark, H. W. 83
Cody, B. L. ('44) R-63
Cranch, E. T. ('43) 103, 157, 204
Cranch, E. T. 107

D

Davis, B. H. ('43) 112
Davis, Walker B. ('43) 80
Dawson, F. M. and Kalinske, A. A. 233
Decher, Edward P. 177
Drier, Douglas E. 203

E

Edwards, A. M. ('44) R-111
Eisner, Benjamin ('44) R-204
Elinssen, Rolf Mag. 187, 211
Enslow, L. H. ('43) 239
Esty, Roger W. ('44) R-118
Esty, Roger W. ('43) 106, 119, 201
Esty, Roger W. 105

F

Fischer, A. J. and Hillman A. ('43) 161
Franklin, W. M. ('44) 221
Fugate, G. L. ('42) 114
Fuller, Harry U. 116
Fuller, Nelson M. ('43) 187

G

Gibson, James E. 96
Gilcreas, F. W. 133
Gifft, H. M. 40, 156
Glace, I. M. (See Krum, H. J.) ('44) R-151
Glover, W. W. 256
Goehring, E. C. ('43) 155
Goetz, John A. and Coventry, F. L. ('43) 98
Goetz, John A. ('44) R-164
Goff, Wm. A. ('44) R-194
Goudey, R. F. 23
Gross, D. D. ('44) R-172
Gunderson, N. E. ('44) R-112

H

Haentjens, W. D. ('43) 40
Hale, Frank E. ('43) 139
Hanes, G. C. (See Nester, N. W.)
Haseltine, T. R. 197
Hay, Harold R. ('44) Mag. 211
Hedgepeth, L. L. and Potter, J. M. ('44) R-241
Hess, Seth G. ('43) 188
Heukelekian, H. ('42) 203
Hirsch, A. A. ('43) 236
Hirsch, A. A. ('44) R-184
Hirsch, A. A. 50, 154
Hommon, Chas. C. 237
Hood, John W. ('42) 197
Hoover, Chas. P. ('43) 100, 144
Horn, W. Walter ('44) R-109
Hotchkiss, Henry T. ('43) 159
Howard, Paul F. 47
Howard, R. R. Mag. 192
Howson, Louis R. ('43) 21
Howson, Louis R. ('44) R-79

K

Kalinske, A. A. (See Dawson, F. M.)
Kappe, S. E. ('43) 231
Kieth, Donald R. 274
Killam, Elson T. ('43) 235
Killam, Elson T. ('44) R-253
King, Arthur C. ('43) 110
King, Henry R. ('44) R-205
Kin, Stephen R. 212
Kin, Stephen R. (See Symons, George E.)
Kivell, W. A. and Lund, N. B. ('41) 144
Krum, H. J. and Glace, I. M. ('44) R-151

L

La Due, W. R. Mag. 181
Lauter, Carl J. ('41) 95
Leipold, Carl 18
Lordley, H. E. 139, 141
Lucoff, Julius ('44) R-143
Lund, N. B. (See Kivell, W. A.)

M

Malcolm, W. L. ('44) Mag. 227
Martin, George 263
Mathis, Alice L. 262
Mavis, F. T. ('44) R-262
Mick, K. L. ('43) 248
Montgomery, James M. ('43) 123
Montgomery, James M. 37
Moore, Chas. E. 109
Moseley, Alex W. ('42) 59
Murdoch, John H. ('43) 23

Mc

McAmis, J. W. ('44) R-246
MacMahon, J. D. (See Synan, John F.)

N

Nester, N. W. and Hanes, G. C. Mag. 206
Neubling, Emil L. 266
Niles, A. H. 259
Norman, Earl E. ('43) 83

O

Olewiler, G. M. ('44) R-199

P

Palmer, H. K. ('42) 58
Palen, V. W. ('44) R-43
Patrick, J. G. ('44) R-157
Perryman, John M. 61, 64
Phillips, Robert S. ('42) 159
Phillips, R. S. ('44) R-147
Pomeroy, Richard ('42) 250
Pond, M. A. 117
Portland Cement Association 169
Poston, H. W. 155, 159
Potter, J. M. (see Hedgepeth, L. L.)
Preston, George (see Brown, Thomas)

Q

Quinn, R. J. and Carr, Ralph L. ('41) 117

R

Radcliffe, D. M. ('44) R-66
Rapp, W. M. ('44) R-75
Rawn, A. M. ('43) 182, 183, 246, 264, 265
Rawn, A. M. 181
Regester, Robert T. 34
Reny, F. J. ('41) 74
Rice, Owen 151
Richardson, C. A. ('41) 25
Richardson, Chas. G. Mag. 198
Riddick, Thomas M. ('44) R-133
Rogers, Sherman L. ('42) 109
Roe, Frank C. ('43) 266
Rudolfs, Willem ('43) 261
Ruehl, E. H. ('44) R-115
Ryon, Henry 53, 249

S

Saunders, Daniel J. ('44) R-141
Schaphorst, W. F. ('42) 270, 274, 278
Schaphorst, W. F. ('44) R-184, R-250
Schaphorst, W. F. 280, 281
Schumpert, H. W. ('44) R-143
Sigworth, E. A. 125
Soden, A. L. 253
Sperry, W. A. ('44) R-247
Smith, Marsden C. ('44) R-37
Smith, Marsden C. 111
Staub, William S. ('42) 89
Staub, Wm. S. 89
Sudrabin, Leon P. 67
Symons, George E. ('44) R-175
Symons, George E. and Crane, Frederick W. ('44) R-166
Symons, George E. and Kin, Stephen R. ('42) 236
Synan, John F., MacMahon, J. D., and Vincent, G. P. 129

T

Tarrant, J. 191, 270
Taylor, D. R. ('42) 74, 104
Taylor, D. R. ('43) 51
Taylor, D. R. ('44) R-36, R-101
Taylor, Stephen H. 19
Thompson, L. N. ('44) R-161
Thoresen, T. C. ('44) R-45
Travaini, D. ('43) 243
Trentlage, La Verne ('43) 113
Turner, H. G. 145

U

U. S. Pub. Health Serv. ('43) 125

V

Van Horn, W. (See Warnick) ('44) R-127
Van Kleeck, Le Roy W. ('44) R-249
Veatch, N. T. 15
Velzy, Charles R. 245
Vincent, G. P. (See Synan, John F.)

W

Warrick, L. F., Wirth, H. E., Van Horn, W. ('44) R-127
Watkins, W. W. ('43) 194
Watson, John D. ('44) R-192
Whitman, N. D. ('44) R-263
Weber, C. G. ('43) 217
Weir, Paul ('43) Mag. 189
Weir, Paul 119
Wiest, Gordon J. ('44) R-252
Wilson, Carl ('43) 121
Wilson, E. K. ('44) R-105
Wilson, P. S. ('43) 87, 117
Wilson, P. S. 43
Wirth, H. E. (See Warrick)
Wirts, John J. ('44) R-222
Wisely, W. H. ('44) R-187, R-211
Wittwer, Norman C. ('44) R-227, R-255
Wittwer, Norman C. 215

Total Pages This Issue—422

Index TO ADVERTISERS

For the Classified Index of Products See Page R-2

A

Albright & Friel, Inc. ... 116
Allen Billmyre Co. ... 101
Aluminum Co. of America ... 13
Alvord, Burdick & Howson ... 116
Ambursen Dam Co. ... 85
American Brass Company, The ... 4-R-174-175
American Car & Fdry. Co. ... 12
American Cast Iron Pipe Co. ... 42
American Hard Rubber Co. ... 105
American Locomotive Co. (Alco Products Div.) ... 91
American Norit Co. ... 104
American Radiator & Standard Sanitary Corp. ... 118-R-214
American Meter Co. ... 24
American Well Works ... 14
Anthracite Equipment Co. ... 94-R-144
Aurora Pump Co. ... 84
Atlas Mineral Products Co. of Pa., The ... 102-R-81

B

Bailey Meter Co. ... R-28
Baker, Jr., Michael ... 116
Barrett Haentjens & Co. ... R-56
Black & Veatch ... 116
Blake, Frank N. ... 118
Bogert, Clinton L. ... 116
Bridgeport Brass Co. ... 43
Buck, Seifert and Jost ... 116
Buffalo Gasoline Motor Co. ... 92
Builders-Providence, Inc. ... 21
Burgess-Manning Company ... 18-R-32-33
Burns & McDonnell ... 116
Byers Co., A. M. ... 17

C

Calgon, Inc. ... 45-R-150
Camp, Thos. R. ... 116
Carborundum Co., The ... 47
Carter Company, Ralph B. ... 22-R-248
Cast Iron Pipe Research Assn. ... 44
Cement Gun Co. ... 111
Central Fdry. Co., The ... 84
Centriline Corp. ... 36
Chain Belt Company ... 98
Chemical Equipment Co. ... 106-R-135
Chester Engineers, The ... 116
Chicago Bridge & Iron Co. ... 11-R-58-R-59
Chicago Pump Company ... 83-R-202
Chapman Valve Mfg. Co., The ... Second Cover
Climax Engr. Co. ... 25
Cole Manufacturing Co., R. D. ... R-60
Collins Engineering Co. ... 116
Columbia Chemical Division ... R-160
Cook, Inc., A. D. ... 97
Cooper-Bessemer Corp. ... 28

D

Darco Corp. ... 86
Dayton-Dowd Co. ... 107
Dearborn Chemical Co. ... 51
De Laval Steam Turbine Co. ... 16
DeLeuw, Cather & Co. ... 116
Deming Co., The ... R-48-R-49
Diamond Alkali Company ... 15
Dorr Company, Inc., The ... Third Cover
Dow Chemical Co. ... R-264
Dracco Corp. ... 101

E

Economy Pumps, Inc. ... 96
Eddy Valve Company ... 113
Edson Corporation, The ... 102
Electro Rust Proofing Co. ... 107
Everson Mfg. Co. ... 119-120

F

Fay, Spofford & Thorndike ... 116
Ferguson, S. F. ... 113-116
Fibre Conduit Co. ... 106
Fisher Research Laboratory ... 115
Fitzgerald, J. C. ... R-180
Flexible Sewer Rod Equipment Co. ... 95-R-190
Flexible Underground Pipe - Cutting Co. ... 95-R-190
Ford Meter Box Co. ... 110
Fulton, Edward A. ... 116

G

Gannett, Fleming, Corddry & Carpenter, Inc. ... 116
General American Transportation Corp. ... 6
General Chemical Co. ... 49
General Electric Co. ... 8-9
General Paint Corp. ... 102-R-87
Glace, I. M. ... 116
Golden-Anderson Valve Spec. Co. ... 114-R-66
Gorman-Rupp Co., The ... 26
Grancell, I. H. ... 115
Greeley & Hansen ... 116

H

Havens & Emerson ... 116
Hayden, Harding & Buchanan ... 116
Haydock, Chas. ... 116
Hays Mfg. Co. ... 93
Heilige, Inc. ... 113
Hill, Hubbell & Co. ... 102-R-87
Homelite Corp. ... 50
Hood Chemical Co. ... 10
Hooker Electrochemical Co. ... 95-R-201
Hydraulic Development Corp. ... 23-R-82

I

Industrial Chemical Sales ... 7-Facing R-1
Inertol Co., Inc. ... 118
Infilco, Incorporated ... 31-R-122-123
Innis, Speiden & Co. ... R-244
Iowa Valve Co. ... 107

J

Jeffrey Manufacturing Company ... 89-R-194-195
Johns-Manville ... 46-R-92-93-94-95
Jones & Henry ... 116
Josam Manufacturing Co. ... R-232

K

Klett Mfg. Co. ... 105
Knowles, Inc., Morris ... 117

L

Lakeside Engr. Co. ... 107
Layne and Bowler, Inc. ... 118
Leadite Company ... 108
Leopold, Inc., F. B. ... 118-R-124
Link-Belt Company ... R-184-185
Le Roi Co. ... 37-38
Leupold & Stevens Instruments ... 33
Lock Joint Pipe Co. ... 41
Lozier, Inc., Wm. S. ... 117
Ludlow Valve Mfg. Co., Inc. ... 30
Luther & Wood ... 104

M

M. & H. Valve & Fitting Co. ... R-102
Mathews Hydrants ... 35
Mathieson Alkali Co. ... 29
Metcalf & Eddy ... 117
Mine Safety Appliances Co. ... R-176
Morris Machine Works ... 90
Mueller Brass Company ... R-22
Mueller Company ... 107
Murray Laboratory ... 117

N

National Clay Pipe Mfrs., Inc. ... 88
National Water Main Clean. Co. ... R-88
Neptune Meter Company ... 54
Niagara Alkali Co. ... 19-20
Nichols Engr. Research Corp. ... R-183
Nooter Boiler Works Co., John ... R-257
Northrop & Company, Inc. ... R-114-R-115
Nussbaumer & Clarke, Inc. ... 117

O

Oliver United Filters ... Facing R-169
Omega Machine Co. ... 100-R-138

P

Pacific Flush-Tank Company ... 111-R-136
Parsons, Brinckerhoff, Hogan & MacDonald ... 117
Peerless Pump Division ... 103
Pennsylvania Salt Mfg. Company ... 5-R-242-R-243
Permutit Co., The ... 93-R-127
Phelps Dodge Refining Corp. ... 105
Philadelphia Quartz Co. ... R-140
Phipps & Bird, Inc. ... 114
Pirnie, Malcolm ... 117
Pitometer Co., The ... 117
Pittsburgh-DesMoines Steel Co. ... R-57
Pittsburgh Equitable Meter Company ... 100
Pittsburgh Plate Glass Co. ... R-146
Porter Co., Inc., H. K. (Quimby Pump Div.) ... 39
Proportioneers, Inc. ... 52-R-165-166-167-168

R

Regester, Robt. T. ... 117
Rensselaer Valve Co. ... 109-R-196
Riddick, Thomas M. ... 117
Ridge Tool Co., The ... 102
Robert and Co. ... 117
Roberts Filter Mfg. Co. ... 1
Rodney Hunt Mach. Co. ... 116
Roots-Connersville Blower Corp. ... 109-R-196
Ross Valve Mfg. Company ... R-65
Royer Foundry & Mach. Co. ... R-258
Russell & Avon ... 117

S

Scientific Concrete Service Corp. ... 116
Sergeant Pulp & Chemical Co., Inc. ... 115
Simplex Valve & Meter Co. ... 39-R-27
Sirrine & Company, J. E. ... 117
Smith Mfg. Co., The A. P. ... 40
Smith & Associates, Benj. L. ... 117
Smith Co., S. Morgan ... 87
Solvay Sales Corp. ... 94
Salomon & Bro., L. A. ... 104
Sparling, R. W. ... 115-R-39
Stanley Engineering Company ... 117
Streamline Pipe & Fittings Division ... R-22
Stuart-Brumley Corp. ... 90-R-136-137

T

Tapax Mfg. Co. ... 81
Tate Pipe Linings, Inc. ... 112
Taylor & Co., W. A. ... 100
Tennessee Corporation ... 86-R-164
Thomson Meter Co. ... 54
Turbine Equipment Co. ... 94

U

U. S. Pipe & Fdry. Co. ... 48-R-[illegible]

V

Vapor Recovery Systems Co. ... R-213
Virginia Smelting Co. ... 112
Vogt Brothers Manufacturing Co. ... 100
Vogt Manufacturing Co. ... 100

W

Wallace & Tiernan Co., Inc. ... Back Cover, R-128-236
Warren Foundry & Pipe Corp. ... 111
Westcott & Mapes, Inc. ... 117
Weston, L. A. ... 104
Weston and Sampson ... 117
Whitman and Howard ... 117
Wilson Chemical Feeders, Inc. ... 102-R-[illegible]
Wood Company, R. D. ... 91
Wyckoff & Son Co. ... 112

Y

Yeoman Bros. Co. ... 27

Z

Zeolite Chemical Co. ... 33

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